

IV. EFFECTS OF THE ACTION

Pursuant to Section 7(a)(2) of the ESA (16 U.S.C. §1536), federal agencies are directed to ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. This biological opinion assesses the effects of NMFS' proposal to continue authorizing the existing Pelagics FMP, as amended, on threatened and endangered species and critical habitat that has been designated for these species. The fisheries authorized under the Pelagics FMP are likely to adversely affect listed species through gear interactions, primarily entanglement and hooking, which may injure or kill individual animals. In the *Description of the Action* section of this Opinion, NMFS provided an overview of the fisheries, particularly the distribution of timing of fisheries that use gear that has been a problem for threatened and endangered species. In the *Status of the Species* (which is also the *Environmental Baseline*) section of this Opinion, NMFS provided an overview of the threatened and endangered species that are likely to be adversely affected by fisheries authorized under the Pelagics FMP.

In this section of a biological opinion, NMFS assesses the probable direct and indirect effects of the fisheries authorized under the Pelagics FMP on threatened and endangered species and designated critical habitat. The purpose of this assessment is to determine if it is reasonable to expect that the fisheries can be expected to have direct or indirect effects on threatened and endangered species that appreciably reduce their likelihood of surviving and recovering in the wild or appreciably diminish the value of designated critical habitat for both the survival and recovery of threatened and endangered species in the wild. Before beginning our analyses, we will discuss our approach to the assessment, the evidence available for our assessment, and assumptions we had to make to overcome limits in our knowledge.

A. Approach to the Assessment

Regulations that implement section 7(b)(2) of the ESA require biological opinions to evaluate the direct and indirect effects of federal actions to determine if it would be reasonable to expect them to appreciably reduce listed species' likelihood of surviving and recovering in the wild by reducing their reproduction, numbers, or distribution (16 U.S.C. §1536; 50 CFR 402.02). Section 7 of the ESA and its implementing regulations also require biological opinions to determine if federal actions would appreciably diminish the value of critical habitat for the survival and recovery of listed species (16 U.S.C. §1536; 50 CFR 402.02). Since the proposed action is not likely to affect designated critical habitat, this Opinion will focus only on the jeopardy analysis.

We approach jeopardy analyses in three steps. First, we identify the probable direct and indirect effects of an action on the physical, chemical, and biotic environment of the action area. The second step of our analysis determines if we would reasonably expect threatened or endangered species to experience reductions in reproduction, numbers, or distribution in response to these effects. In the third step of our analyses, we determine if any reductions in a species' reproduction, numbers, or distribution (identified in the second step of our analysis) can be expected to appreciably reduce a listed species' likelihood of surviving and recovering in the wild.

Human activities can reduce a species' reproduction by reducing the number of adults that reproduce in a population, reducing the number of young an adult will produce in a time interval or a lifetime, increasing the time it takes for an adult to reproduce, increasing the number of years that pass before an adult females returns to breed, reducing the survival of young, or decreasing the number of young that recruit into the adult population (Andrewartha and Birch, 1954; Ebert, 1999; Caughley and Gunn, 2000). Human activities can reduce a species' numbers by killing them immediately or over time, reducing the numbers of individuals born into a population, reducing the number of individuals that immigrate into a population, or increasing the number of individuals that emigrate from a population (Burgman *et al.*, 1993, Caughley and Gunn, 2000). Human activities can reduce a species' distribution by reducing its population size or density in ways that cause the species to abandon parts of its range (Fowler and Baker, 1991). A species' reproduction, numbers, and distribution are interdependent: reducing a species' reproduction will reduce its population size; reducing a species' population size will usually reduce its reproduction, particularly if those reductions decrease the number of adult females or the number of young that recruit into the breeding population; and reductions in a species' reproduction and population size normally precede reductions in a species' distribution.

The final step in our analysis — relating reductions in a species' reproduction, numbers, or distribution to reductions in the species' likelihood of surviving and recovering in the wild — is the most difficult step because (a) the relationship is not linear; (b) to persist over geologic time, most species' have evolved to withstand some level of variation in their birth and death rates without a corresponding change in their likelihood of surviving and recovering in the wild; (c) our knowledge of the population dynamics of other species and their response to human perturbation is usually too limited to support anything more than rough estimates. Nevertheless, our analysis must distinguish between anthropogenic reductions in a species' reproduction, numbers, and distribution that can reasonably be expected to affect the species' likelihood of survival and recovery in the wild from other (natural) declines.

Error

As scientists we have two points of reference available when we consider data, information, or other evidence to support our analyses (1) we can analyze the information available to avoid concluding that an action had an effect on listed species or critical habitat, when, in fact, it did not or (2) we can analyze the information available to avoid concluding that an action had no effect on listed species or critical habitat when, in fact, the action had an effect. In statistics, these two points of reference are called "errors": the first point of reference is designed to avoid what is called Type I error while the latter is designed to avoid what is called Type II error (see Cohen, 1987). Although analyses that minimize either type of error are statistically valid, most biologists and ecologists still focus on minimizing the risk of concluding that there was an effect when, in fact, there was no effect (Type I error) and tend to ignore Type II error.

To comply with direction from the U.S. Congress to provide the "benefit of the doubt" to threatened and endangered species [House of Representatives Conference Report No. 697, 96th Congress, Second Session, 12 (1979)], our analyses are designed to avoid concluding that actions had no effect on listed species or critical habitat when, in fact, there was an effect (Type II error). This approach to

error may lead us to different conclusions than scientists who take a more traditional approaches to avoiding error, but we believe our approach is more consistent with the purposes of the ESA and direction from Congress.

Jeopardy analyses must look into the future to identify the effects of activities conducted today on the future of threatened and endangered species. Some human activities have delayed effects on plant and animal populations, either because a species' population takes time to respond to an effect, because the population only responds when effects accumulate, or a combination of these two. The classic example of a combined response is bald eagle population's response to DDT, which became apparent only after many years of population declines. These responses pose the challenge of choosing how far into the future we must look to (1) detect a population's response to an effect or (2) detect a change in a species' likelihood of surviving and recovering in the wild (Crouse, 1999). If we do not look far enough into the future, our analyses will not detect a population's response to a human activities and we are more likely to falsely conclude there was no effect when, in fact, an effect occurred (which means, in the case of fisheries, adult and subadult turtles will have been captured and killed for a period of years. If we look too far into the future, our analyses can mask short-term collapses in a population and, again, we increase our likelihood of falsely concluding there was no effect when, in fact, an effect occurred.

In this Opinion, we will respond to this challenge by basing our projections on the time it would take individuals born in the current year (2001) to enter the adult population and breed. This is consistent with approaches population biologists normally use when addressing life tables, which follow a population's patterns of survival and fecundity from birth to death (for age-based models) or from eggs to adults (for stage-based approaches). Since these life tables form the foundation for quantitative assessments of a population's risk of extinction or explosion such as population viability analyses (see Burgman *et al.*, 1993; Caughley and Gunn, 1999; Heppell *et al.*, 1999), we will use the same approach for our qualitative assessment. We will apply this approach by assessing the projecting the effects of the proposed fisheries on the turtles' survival and fecundity over the time it would take the 2001 cohort of hatchlings to recruit into the adult, breeding population.

Evidence Available for the Assessment

Detailed background information on the status of these species and critical habitat has been published in a number of documents including recent status reviews of sea turtles (NMFS and USFWS, 1995; USFWS, 1997); recovery plans for the eastern Pacific green turtle (NMFS and USFWS, 1998a), U.S. Pacific populations of hawksbill sea turtles (NMFS and USFWS, 1998b), loggerhead sea turtle (NMFS and USFWS, 1991), leatherback sea turtle (NMFS and USFWS, 1992), and U.S. Pacific populations of olive-ridley sea turtles (NMFS and USFWS, 1998c); and reports on interactions between sea turtles and gear used in pelagic fisheries (Bolten *et al.*, 1996). In addition, Crouse *et al.* (1987), Crowder *et al.* (1994), Heppell (1998), Heppell *et al.* (1996, 1999, and 2000) published results from population models, sensitivity analyses, and elasticity analyses for various species of marine turtles, although most models are based on data on loggerhead sea turtles in the Atlantic Ocean.

Despite this published information, our knowledge of the biology and ecology of sea turtles, including their life history, population dynamics, and their response to environmental and other variation is still rudimentary. The National Research Council (1990) identified many of these limits and recommended research on a wide array of variables, including age at reproductive maturity, age-specific rates of survivorship and fecundity, distribution, and migration. Wetherall (1996, *in* Bolten *et al.* 1996) further described limitations in our understanding and, consequently, concluded that even the results of population models would be little more than guesses with untested critical assumptions. Bolten *et al.* (1996) concluded that developing analytical tools to support assessments like the one we must conduct in this Opinion requires much more information than is currently available. Pritchard (1996) concluded that we do not currently have enough life history data on sea turtles to construct models that can be used for predictive purposes. As a result of these limits, we cannot quantify the effects of changes in abundance, reproductive success, and other vital rates on a sea turtle's likelihood of surviving and recovering in the wild.

In the 1998 Opinion on the western Pacific pelagics fisheries, NMFS used a simulation model (called the TURTSIM model) in an attempt to overcome the limits in our knowledge of the population dynamics of sea turtles. After issuing the 1998 Opinion, NMFS examined the model further and concluded that, without more information on the biology and ecology of sea turtles, the model did not have the resolution necessary to identify the effects of the fisheries on sea turtles. Although NMFS concluded that the fisheries were not likely to jeopardize the continued existence of threatened or endangered sea turtles based on the results of those simulations, it would have been difficult for the model to separate the effects of the fisheries covered by the Pelagics FMP from the effects of all Pacific fisheries given the limits of our understanding.

Assumptions Made to Overcome Limits in our Knowledge

While the limits in our understanding we discussed in the preceding section remain, and while models like TURTSIM undergo further development, we will use a conceptual life history and population model to conduct our effects' analysis. In the absence of specific information on the likelihood of threatened and endangered sea turtles surviving and recovering in the wild, we used the extensive body of information on the population dynamics of small and declining populations (for example, see summaries presented in Soulé, 1986, Burgman *et al.*, 1993, Caughley, 1994, Meffe and Carroll, 1997, Primak, 1998, and Caughley and Gunn, 1999). These authors identify general patterns that small and declining populations follow, which we will use to make inferences about the effects of the proposed fisheries on listed species or the species' response to those effects. In particular, we rely on these patterns to make inferences about the sea turtles' likelihood of surviving and recovering in the wild.

In general, a species' response to human actions will depend on several variables, including the number of populations that comprise the species; the distribution and size of these populations; the number, size, and distribution of sub-populations in each population; the structure (distribution of ages or stages in a population), composition (gender relationships), and vital rates (rates of birth, death, immigration, and emigration) of each population; and the ecological and social relationships between individual members of the species and their environment (Andrewartha and Birch, 1954; Lawton, 1995).

The status and trends of most populations are usually discussed in terms of their vital rates: rates of birth, death, immigration, and emigration (Burgman *et al.*, 1993; Caughley, 1994; Lawton, 1995). Populations whose average birth (or immigration) rates are higher than or equal to their average death (or emigration) rates will remain stable over time. Populations whose average birth rates are lower than or equal to their average death rates will decline. The rate of these declines will reflect the difference between the birth and death rates; the greater the difference between their birth and death rates, the faster the rate of decline. If a population's mean death rate consistently exceeds its mean birth rate, the population will not survive over any long period of time (Mangel and Tier, 1994; Caswell, 2001).

Many species that are currently listed as threatened or endangered experienced two kinds of population processes on their path to endangerment: (1) population processes that caused the species' total abundance to decline until it was a percentage of historic abundance and (2) population processes that affected the species once its population was small which can cause the species' to become extinct without any new human threats (Simberloff, 1986; Caughley, 1994; Lawton, 1995). Once populations become small, they become more susceptible to (a) changes in birth rates, death rates, and emigration rates, that further reduce their population size; and (b) genetic factors that increase their risk of inbreeding depression or reduce their ability to adapt to environmental change, which combine to (c) increase the ability of environmental variation to cause the population to decrease (Shafer and Samson, 1985; Gilpin and Soulé, 1986; Primack, 1993; Caughley, 1994). Small populations are also vulnerable to population declines caused by low population densities, changes in sex ratios, and changes in the annual production of young. In small populations, small changes in birth, death, immigration, and emigration have increasingly significant effects on a population's status and trend (Caughley 1994). For example, small reductions in reproduction and numbers can significantly reduce a species' reproduction, numbers, distribution, and its likelihood of surviving or recovering in the wild. Finally, small populations face a high risk of extinction caused by catastrophic events, which can be more significant than any other threat (Mangel and Tier 1994).

Because of these characteristics, small populations are less likely to survive (that is, they have much higher risks of extinction) than other populations and are less able to recover from further declines caused by natural or human-related phenomena. Additional human activities that reduce a species' reproduction, numbers, or distribution usually decrease the species' likelihood of surviving and recovering in the wild.

To assess the potential effects of reductions in sea turtle reproduction, numbers, or distribution on the turtles' likelihood of surviving and recovering in the wild, we used a conceptual model of sea turtle life history. To compensate for a high mortality rate of eggs, hatchlings, and small juveniles each year, sea turtles have evolved a life history strategy that requires adults to produce large numbers of eggs each year, live for many years, and breed repeatedly (National Research Council 1990). Through this life history strategy, the long lives of adult turtles buffers the turtles from dramatic fluctuations caused by large fluctuations in egg, hatchling, and juvenile survival (Crouse 1999). Now that these species of sea turtles are endangered, however, we assume that the long lives of adult turtles *mask* the effect of previous losses of eggs, hatchlings, and juveniles on the turtle populations (see Crouse 1999). As a

result, we allow that sea turtles probably face a higher risk of extinction than our knowledge allows us to recognize and allow that our assessment probably underestimates the effects of the fisheries on turtles (see Ludwig *et al.* 1993).

Application of this Approach to the Species Considered in this Opinion

We begin these analyses with an implicit understanding that the sea turtles considered in this Opinion are threatened with global extinction by a wide array of human activities and natural phenomena; we have outlined many of those activities in the *Status of the Species* section of this Opinion. We also recognize that some of these other human activities and natural phenomena pose a much larger and more serious threat to the survival and recovery of sea turtles (and other flora and fauna) than the U.S. Pacific pelagics fisheries. Further, we recognize that we will not be able to recover sea turtles without addressing the full range of human activities and natural phenomena that could cause these animals to become extinct in the foreseeable future (USFWS and NMFS 1997). Nevertheless, this Opinion focuses solely on the direct and indirect effects of the U.S. Pacific pelagics fisheries managed under the Western Pacific Pelagics FMP on threatened and endangered sea turtles. NMFS will consider the effects of other actions on threatened and endangered turtles as a separate issue.

We will treat sea turtle populations in the Pacific Oceans as distinct populations from the Atlantic Ocean populations for the purposes of this consultation (except the olive ridley turtle, which is limited to the Pacific basin). We believe this approach is allowable based on interagency policy on the recognition of distinct vertebrate populations (Federal Register 61: 4722-4725). To address specific criteria outlined in that policy, sea turtle populations in the Pacific basin are geographically discrete from populations in the Atlantic basin, with limited genetic exchange (see NMFS and USFWS 1998a). The loss of sea turtle populations in the Pacific basin would result in a significant gap in the distribution of each turtle species, which makes these populations biologically significant. Finally, the loss of these sea turtle populations in the Pacific basin would dramatically reduce the distribution and abundance of these species and would, by itself, appreciably reduce the entire species' likelihood of surviving and recovering in the wild.

To conduct our jeopardy analyses, we will evaluate the information available on the numbers of sea turtles captured, injured, or killed in the U.S. Pacific pelagic fisheries to determine if these injuries or deaths can be expected to reduce a species' reproduction, numbers, or distribution. As part of these analyses, we made assumptions about the number of adult, female sea turtles that might be captured, injured, or killed in the pelagic fisheries. As we discussed earlier, we will project the effects of the proposed fisheries on the turtles' survival and fecundity over the time it would take the 2001 cohort of hatchlings to recruit into the adult, breeding population.

We consider these reductions within the context of the species' status and trend. We estimate the relative abundance of sea turtle populations based on the numbers of adult females, usually as they return to their nesting beaches. As a result, our population estimates will generally change only in response to changes in (1) the death rate of adult females, (2) the recruitment rate of sub-adult females, (3) the interval between a female's return to nesting beaches, and (4) migration patterns that might

cause females to nest on other, uncensused, beaches (given the strong tendency of female turtles to return to the beach of their birth, we discount this latter phenomenon as having minimal effect on population trends). Over any five-ten year interval, the size of sea turtle populations will only change in response to changes in death rates and changes in recruitment rates (this time interval should be long enough to mask differences in re-nesting intervals). Therefore, if a turtle population is increasing, we can infer that the average number of females that recruit into the adult population is greater than the average number of adults that die in the population. If a turtle population is stable, we can infer that the average number of females that recruit into the adult population equals the average number of adults that die in the population. If a turtle population is decreasing, we can infer that the average number of females that recruit into the adult population is less than the average number of adults that die in the population.

If we conclude that the number of turtles captured, injured, or killed in the fisheries would reduce the species' reproduction, numbers, or distribution, we will consider the effects of those reductions on the species' likelihood of surviving and recovering in the wild. We will conduct this inquiry by considering the probable effects on those reductions on the species' population structure, the status and trends of the various populations, the vital rates, and the relationship between vital rates and the population's status and trend (that is, the population's rates of increase). Specifically, we will consider whether additional, human-related mortalities associated with the fisheries are a significant or chronic source of reduced fecundity in the adult population or decreased rates of survival in one or more life history stages of these sea turtles. If the fisheries can be expected to have significant, adverse effects on a life history stage that would translate into reduced numbers of breeding sea turtles, we will assume this will reduce the numbers of eggs and hatchlings over the next breeding cycle, which would be expected to reduce the size of these turtle populations in subsequent generations.

If we conclude that the fisheries are likely to take threatened or endangered turtles or if we conclude that the proposed fisheries are likely to jeopardize the continued existence of one or more species of turtles, we are required by law to recommend alternatives that minimize the impact of the take on listed species or remove the likelihood of jeopardy. Obviously, any recommendations we provide in this Opinion (in the form of reasonable and prudent alternatives or reasonable and prudent measures) will only address problems associated with the U.S. Pacific pelagics fisheries and will not eliminate all of the threats to these species. However, these species, like most other species, became threatened with extinction through the cumulative effects of many actions over time. They are most likely to recover by following the reverse path: through the cumulative effects of many actions over time (Clark *et al.*, 1994; Caughley and Gunn, 1999).

B. Conservation and Management of Listed Species under the Magnuson-Stevens Act and the Pelagics Fishery Management Plan

Two of the ten national standards set out by the MSA are relevant to the effects the MSA and the Pelagics FMP are expected to have on the listed species. As further discussed in the next section, the primary effect of the Pelagics FMP and the fisheries authorized under that FMP is the incidental capture, injury, and mortality of listed species by fishing gear. National standards 1 and 9, as seen in

Table IV-1 below, guide the amount of effort and associated bycatch that shall be permitted under an FMP.

Table IV-1: MSA National Standards (16 U.S.C. 1851, Sec. 301(a)).

(a) IN GENERAL. – Any fishery management plan prepared, and any regulation promulgated to implement any such plan, pursuant to this title shall be consistent with the following national standards for fishery conservation and management:	
(1)	Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.
(9)	Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

The Pelagics FMP currently has a non-numerical definition of optimum yield (OY) which is as follows: “OY is the amount of each management unit species or species complex that can be harvested by domestic and foreign fishing vessels in the EEZ and adjacent waters to the extent regulated by the FMP without causing 'local overfishing' or 'economic overfishing' within the EEZ of each island area, and without causing or significantly contributing to 'growth overfishing' or 'recruitment overfishing' on a stock-wide basis” (WPRFMC 1998b). Given that little is known about the status of most of the PMUS, this definition of OY could equate to unrestricted fishing effort under the FMP.

There are two regulations which limit fishing effort under the FMP. Primarily, the limited entry permit and maximum boat-length for the Hawai'i based longline fishery holds the amount of effort possible in that fishery to the maximum effort those permitted boats can sustain. The 25 to 75 nm zone, established to protect Hawaiian monk seals and to eliminate gear conflicts between fisheries, also serves to limit fishing effort in certain areas by prohibiting longline fishing, but still allows other gear types. There are no other regulations under the FMP which serve to control the amount of fishing effort that can occur. In addition, under the proposed action, the Pelagics FMP does not include other conservation and management objectives which are designed to minimize the amount of bycatch of listed species.

Therefore, under the proposed action, NMFS expects that fishing effort in many of the fisheries under the FMP will continue at approximately the same levels as they have in previous years. Effort in some fisheries, such as the Hawaii-based longline fishery and the American Samoa longline fishery, has been increasing and this trend is expected to continue. NMFS anticipates that, due to the lack of measures to avoid or reduce the amount of bycatch and mortal bycatch of listed species, these interactions will continue with the same frequency and effect as they have in the past; in some fisheries, overall take levels of listed species may increase.

C. Effects of Fisheries Authorized Under the Pelagics FMP

Determining the scope and magnitude of impacts of any fishery on sea turtle populations is complicated by the fact that all of these species lead an oceanic existence during most of their life history. There are broad gaps in our knowledge of sea turtles in the marine environment due to the difficulties in studying

them away from their nesting beaches. Recent technological developments in satellite telemetry and genetic analyses are rapidly expanding our knowledge on the movements and habits of sea turtles in the marine environment, but much remains unknown. In contrast, at certain nesting beaches, reasonably good ecological data exist for the breeding phase when adult females, eggs, and hatchlings are accessible. The leatherbacks and olive ridleys are the most pelagic species, living well offshore from the time they leave the beach as hatchlings until they return to breed as adults. Others, such as the green and the loggerhead, inhabit coastal waters as adults, but spend varying segments of their immature life in the open ocean. Even then, the adults regularly undertake breeding migrations over deep water.

In general, there are five different fishing gears used to capture pelagic species under the western Pacific Pelagics Fishery Management Plan. They are troll, handline, pole-and-line, and longline gear. The type of fishing gear used and the area fished will affect the likelihood of an interaction with a sea turtle. Below is a discussion of the likelihood of various types of gear and an interaction with a sea turtle.

1. Troll fishing gear

Trolling is conducted by towing lures or baited hooks from a moving vessel, using big-game-type rods and reels as well as hydraulic haulers, outriggers, and other gear. Up to six lines rigged with artificial lures or live bait may be trolled when outrigger poles are used to keep gear from tangling. When using live bait, trollers move at slower speeds to permit the bait to swim naturally (WPRFMC, 1995). Freshly caught small yellowfin tuna or skipjack tuna may be used as live bait to attract marlin. Once a fish is hooked, the gear is immediately retrieved.

Although trolling occurs in areas where sea turtles are also found, there have been no reported interactions by vessel operators. In addition, sea turtles are not likely to interact with troll fishing gear because the gear is towed through the water faster than sea turtles may be traveling. Furthermore, sea turtles do not prey on the same type of prey as used by the troll fisheries. A small potential exists that the fishing gear may incidentally hook or entangle a sea turtle when the gear is towed through the water. However, NMFS considers this type of an interaction extremely rare and does not believe trolling gear is likely to adversely affect sea turtle populations.

2. Pole-and-line

There is a small pole-and-line fishery operating from Hawai'i targeting skipjack tuna. It is sometimes referred to as the aku (skipjack tuna) fishery or baitboat fishery. The pole-and-line fishery uses live bait thrown from a fishing vessel (ranging from 65 - 80 feet) to stimulate a surface tuna school into a feeding frenzy. The pole and line used are of equal length (3 meters). Fishing is conducted using a barbless hook with feather skirts slapped against the water until a fish strikes. The hooked fish is then yanked into the vessel in one motion. The fish unhooks when the line is slacked so that the process can be repeated. The bait most often used is anchovy.

Although the pole-and-line fishery occurs where sea turtles also exist, there is a very low likelihood of an interaction with a sea turtle because the turtle would need to be in the vicinity and the fisher would

need to hook the turtle or the turtle would need to strike the hook. This type of an event is unlikely to occur because sea turtles are not likely to prey on anchovy, and the activity of the fish feeding frenzy would deter turtles from remaining in the area. For these reasons, NMFS concludes that the pole-and-line fishery is not likely to adversely affect sea turtle populations.

3. *Handline fishery*

Two types of pelagic handline fishing methods are practiced in Hawai'i, the *ika-shibi* method, and the *palu-ahi* method. The *ika-shibi* or night handline fishery developed from a squid (*ika*) fishery which switched to target the incidental catch of tuna (*shibi*). Lights and chum are used to attract small prey species and larger target tunas to handlines baited with squid. The vessels typically fish between 5 - 6.5 nm from shore. The night-time fishery is mostly conducted off Hilo and off Keahou, both of the island of Hawaii (Hamilton, 1996 *in* NMFS, 2000a).

The *palu-ahi* or day-handline fishery also targets tuna but fishing occurs during the day. A baited hook on the end of a handline is laid against a stone and the line wound around it. Additional pieces of chum are wound into the bundle which is then tied in a slip knot (Rizzuto, 1983 *in* NMFS, 2000a). The bundle is lowered to the preferred depth (commonly 20-30 meters) where the line is jerked to untie the knot so the baited hook and chum are released at the target depth. Fishing usually takes place by smaller vessels within 6.5 nm from shore and by larger vessels around fish aggregating device or around sea mounts and weather buoys (100 - 200 nm from shore). As soon as a fish is caught, the gear is brought back on board.

There have been no reported takes of sea turtles by the handline fishery. Although there is the risk that sea turtles may become hooked or entangled in the fishing gear, any caught animal can be immediately dehooked or disentangled and released. Moreover, most turtles found in the area of the handline fisheries are not likely to prey on the baited hooks. For these reasons, NMFS concludes the handline fishery, as managed under the Pelagics FMP is not likely to adversely affect listed sea turtle populations.

4. *Longline fishery*

Potential impacts from longline fisheries on sea turtles will generally be related to injury or mortality, although the entanglement or hooking episode, whether or not it develops into an injury or mortality, may also impact sea turtles. Injury or mortality of turtles hooked by a long-soaking longline may result from drowning due to forced submergence, and/or impairment or wounds suffered as a result of hooking, either externally or internally. Long-term effects from the hooking or entanglement incident could include reduced locomotive or foraging capability or interruption of migration, breeding and reproduction patterns. Although survivability studies have been conducted on sea turtles taken by the Hawaii-based longline fishery, such long-term effects are nearly impossible to monitor; therefore a quantitative measure of the effect of longlining on sea turtle populations is very difficult. The following subsections detail the general effects to sea turtles interacting with longline gear.

a. Factors contributing to the likelihood of an interaction with the longline fishery

The following subsections describe aspects of longline fishing, including gear characteristics as well as environmental conditions that may contribute to the likelihood of sea turtle interactions with this fishery.

(1) Gear

(a) *Floats*: Sea turtles may be attracted to the floats used on longline gear. Sea turtles have been observed associating with manmade floating objects significantly more frequently than with natural objects, perhaps related to turtles' affinity for three-dimensional objects. Turtles also show a preference for objects floating horizontally and nearly submerged and are strongly attracted to brightly colored objects (Arenas and Hall, 1992). Floats typically used during swordfish-style sets are bright orange, bullet-shaped, and slightly submerged. Tuna-style sets generally use larger cylindrical inflatable or rigid spherical buoys and floats, and these also are typically orange in color (L. Enriquez, NMFS, personal communication, January, 2001; e.g. www.lindgren-pitman.com/floats.htm).

(b) *Bait*: Sea turtles may also be attracted to the bait used on longline gear. Four olive ridleys necropsied after being taken dead by Hawaii-based longliners were found with bait in their stomachs (Work, 2000). In addition, a leatherback has been documented ingesting squid bait on swordfish longline gear. The authors speculate that the lightsticks may initially have attracted the turtle, by simulating natural prey (Skillman and Balazs, 1992).

(c) *Lightsticks*: Sea turtles foraging at night may be attracted to the lightsticks, confusing them for prey. Lightsticks are often used by longliners targeting swordfish in order to attract the swordfish to the bait. Whether lightsticks attract swordfish directly or whether they attract baitfish, which in turn attract the swordfish, is not entirely clear; however, fishermen report higher takes of swordfish when they use lightsticks. Lightsticks are generally attached to every other branchline, approximately a meter above the hook. Researchers studying the prey and foraging habits of sea turtles have reported the ingestion of pyrosomas, the so-called "fiery bodies," by leatherbacks, loggerheads, and olive ridleys; however, there is little information on the actual ingestion of lightsticks by sea turtles. In addition, statisticians have not been able to find any correlation between sea turtle take and the proximity of a lightstick to the hook or branchline that the turtle was hooked on or entangled in.

(2) *Environmental conditions*: Environmental conditions may also play a large part in whether or not a sea turtle interacts with longline gear. Sea turtles in the open ocean are often found associated with oceanographic discontinuities such as fronts and driftlines, areas often indicating high productivity. In addition, sea turtles also appear to associate with particular sea surface temperatures. As mentioned in more detail later, species such as the loggerheads have been tracked moving along convergent ocean fronts, in waters with sea surface temperatures of 17°C and 20°C (Polovina, *et al.*, 2000). Swordfish are caught by longliners in association with frontal zones where ocean currents or water masses meet to create turbulence and sharp gradients of temperature and salinity. Swordfish also make vertical migrations through the water column, rising near to the surface at night from deep waters. Thus, while searching for concentrations of swordfish, longliners set their gear across these temperature gradients ("breaks") indicative of intersecting water masses, and when sea turtles are associated with these fronts, interactions are more likely.

b. General effects of longline fishing on sea turtles

(1) Effects of forcible submergence: Sea turtles can be forcibly submerged by longline gear either through a hooking or entanglement event, where the turtle is unable to reach the surface to breathe. This can occur at any time during the set, including the setting and hauling of the gear, and generally occurs when the sea turtle encounters a line that is too short to reach the surface or is too heavy to be brought up to the surface by a swimming sea turtle. For example, a sea turtle that is hooked on a 3 meter branchline attached to a mainline set at depth by a 6 meter floatline will generally not be able to swim to the surface unless it has the strength to drag the mainline approximately 3 more meters (discussed further below).

Turtles hooked by longline gear will sometimes drag the clip, attached to the branch line, along the main line. If this happens, the potential exists for a turtle to become entangled in an adjacent branch line which may have another species hooked such as a shark, swordfish, or tuna. According to observer reports, most of the sharks and some of the larger tuna such as bigeye are still alive when they are retrieved aboard the vessel, whereas most of the swordfish are dead. If a turtle were to drag the branch line up against a branch line with a live shark or bigeye tuna attached, the likelihood of the turtle becoming entangled in the branch line is greater. If the turtle becomes entangled in the gear, then the turtle may be prevented from reaching the surface. The potential also exists, that if a turtle drags the dropper line next to a float line, the turtle may wrap itself around the float line and become entangled.

Sea turtles that are forcibly submerged by longline gear undergo respiratory and metabolic stress that can lead to severe disturbance of their acid-base balance. While most voluntary dives by sea turtles appear to be aerobic, showing little if any increases in blood lactate and only minor changes in acid-base status (pH level of the blood), sea turtles that are stressed as a result of being forcibly submerged through hooking or entanglement in a line rapidly consume oxygen stores, triggering an activation of anaerobic glycolysis, and subsequently disturbing their acid-base balance, sometimes to lethal levels. It is likely that the rapidity and extent of the physiological changes that occur during forced submergence are functions of the intensity of struggling as well as the length of submergence (Lutcavage and Lutz, 1997). In a field study examining the effects of shrimp trawl tow times and sea turtle deaths, there was a strong positive correlation between the length of time of the tow and sea turtle deaths (Henwood and Stuntz, 1987, *in* Lutcavage and Lutz, 1997).

Sea turtles forcibly submerged for extended periods of time show marked, even severe, metabolic acidosis as a result of high blood lactate levels. With such increased lactate levels, lactate recovery times are long (even as much as 20 hours), indicating that turtles are probably more susceptible to lethal metabolic acidosis if they experience multiple captures in a short period of time, because they would not have had time to process lactic acid loads (*in* Lutcavage and Lutz, 1997). Presumably, however, a sea turtle recovering from a forced submergence would most likely remain resting on the surface (given that it had the energy stores to do so), which would reduce the likelihood of being recaptured by a submerged longline. Recapture would also depend on the condition of the turtle and the intensity of fishing pressure in the area. NMFS has no information on the likelihood of recapture of sea turtles by

the Hawaii-based longline fishery or other fisheries. However, in the Atlantic Ocean, turtles have been reported as captured more than once by longliners (on subsequent days), as observers reported clean hooks already in the jaw of captured turtles. Such multiple captures were thought to be most likely on three or four trips that had the highest number of interactions (Hoey, 1998).

Respiratory and metabolic stress due to forcible submergence is also correlated with additional factors such as size and activity of the sea turtle (including dive limits), water temperature, and biological and behavioral differences between species and will therefore also affect the survivability on a longline. For example, larger sea turtles are capable of longer voluntary dives than small turtles, so juveniles may be more vulnerable to the stress of forced submergence than adults. During the warmer months, routine metabolic rates are higher, so the impacts of the stress due to entanglement or hooking may be magnified. In addition, disease factors and hormonal status may also play a role in anoxic survival during forced submergence. Any disease that causes a reduction in the blood oxygen transport capacity could severely reduce a sea turtle's endurance on a longline, and since thyroid hormones appear to have a role in setting metabolic rate, they may also play a role in increasing or reducing the survival rate of an entangled sea turtle (*in* Lutz and Lutcavage, 1997). Turtles necropsied following capture (and subsequent death) by longliners in this fishery were found to have pathologic lesions. Two of the seven turtles (both leatherbacks) had lesions severe enough to cause probable organ dysfunction, although whether or not the lesions predisposed these turtles to being hooked could not be determined (Work, 2000). As discussed further in the leatherback and loggerhead subsections below, some sea turtle species are better equipped to deal with forced submergence.

Although a low percentage of turtles that are captured by longliners actually are reported dead, sea turtles can drown from being forcibly submerged. Such drowning may be either "wet" or "dry." In the case of dry drowning, a reflex spasm seals the lungs from both air and water. With wet drowning, water enters the lungs, causing damage to the organs and/or causing asphyxiation, leading to death. Before death due to drowning occurs, sea turtles may become comatose or unconscious. Studies have shown that sea turtles that are allowed time to stabilize after being forcibly submerged have a higher survival rate. This of course depends on the physiological condition of the turtle (e.g. overall health, age, size), time of last breath, time of submergence, environmental conditions (e.g. sea surface temperature, wave action, etc.), and the nature of any sustained injuries at the time of submergence (NRC, 1990).

(2) Effects of entanglement: Sea turtles are particularly prone to entanglement as a result of their body configuration and behavior. Records of stranded or entangled sea turtles reveal that fishing debris can wrap around the neck or flipper, or body of a sea turtle and severely restrict swimming or feeding. Over time, if the sea turtle is entangled when young, the fishing line will become tighter and more constricting as the sea turtle grows, cutting off blood flow, causing deep gashes, some severe enough to remove an appendage. Sea turtles have also been found trailing gear that has been snagged on the bottom, thus causing them to be anchored in place (Balazs, 1985).

Sea turtles have been found entangled in branchlines (gangions), mainlines and float lines. Longline gear is fluid and can move according to oceanographic conditions determined by wind and waves, surface

and subsurface currents, etc.; therefore, depending on both sea turtle behavior, environmental conditions, and location of the set, turtles could be entangled in longline gear. Entanglement in monofilament line (mainline or gangion) or polypropylene (float line) could result in substantial wounds, including cuts, constriction, or bleeding on any body part. In addition entanglement could directly or indirectly interfere with mobility, causing impairment in feeding, breeding, or migration. Sea turtles entangled by longline gear are most often entangled around their neck and foreflippers, and, often in the case of leatherback entanglements, turtles have been found snarled in the mainline, floatline, and the branchline (e.g. Hoey, 2000).

(3) Effects of hooking. In addition to being entangled in a longline, sea turtles are also injured and killed by being hooked. Hooking can occur as a result of a variety of scenarios, some of which will depend on foraging strategies and diving and swimming behavior of the various species of sea turtles. For example, necropsied olive ridleys have been found with bait in their stomachs after being hooked; therefore, they most likely were attracted to the bait and attacked the hook. In addition, leatherbacks, loggerheads and olive ridleys have all been found foraging on pyrosomas which are illuminated at night. If lightsticks are used on a swordfish set at night to attract the target species, the turtles could mistake the lightsticks for their preferred prey and get hooked externally or internally by a nearby hook. Similarly, a turtle could concurrently be foraging in or migrating through an area where the longline is set and could be hooked at any time during the setting, hauling, or soaking process.

Sea turtles are either hooked externally - generally in the flippers, head, beak, or mouth - or internally, where the animal has attempted to forage on the bait, and the hook is ingested into the gastro-intestinal tract, often a major site of hooking (E. Jacobson, *in* Balazs, *et al.*, 1995). Even if the hook is removed, which is often possible with a lightly hooked (i.e. externally hooked) turtle, the hooking interaction is believed to be a significant event. Like most vertebrates, the digestive tract of the sea turtle begins in the mouth, through the esophagus, and then dilates into the stomach. The esophagus is lined by strong conical papillae, which are directed caudally towards the stomach (White, 1994). The existence of these papillae, coupled with the fact that the esophagus snakes into an s-shaped bend further towards the tail make it difficult to see hooks, especially when deeply ingested. Not surprisingly, and for those same reasons, a deeply ingested hook is also very difficult to remove from a turtle's mouth without significant injury to the animal. The esophagus is attached fairly firmly to underlying tissue; therefore, when a hook is ingested, the process of movement, either by the turtle's attempt to get free of the hook or by being hauled in by the vessel, can traumatize the internal organs of the turtle, either by piercing the esophagus, stomach, or other organs, or by pulling the organs from their connective tissue. Once the hook is set and pierces an organ, infection may ensue, which may result in death to the animal.

If a hook does not become lodged or pierce an organ, it can pass through to the colon, or even expelled through the turtle (E. Jacobson *in* Balazs, *et al.*, 1995). In such cases, sea turtles are able to pass hooks through the digestive track with little damage (Work, 2000). Of 38 loggerheads deeply hooked by the Spanish Mediterranean longline fleet and subsequently held in captivity, six loggerheads expelled hooks after 53 to 285 days (average 118 days) Aguilar, *et al.* (1995). If a hook passes through a turtle's digestive tract without getting lodged, the chances are good that less damage has been done. Tissue necrosis that may have developed around the hook may also get passed along through the

turtle as a foreign body (E. Jacobson, *in* Balazs, *et al.*, 1995).

(4) Effects of trailing gear Trailing line (i.e. line that is left on a turtle after it has been captured and released), particularly line trailing from an ingested hook, poses a serious risk to sea turtles. Line trailing from an ingested hook is likely to be swallowed, which may occlude the gastrointestinal tract, preventing or hampering foraging, leading to eventual death. Trailing line may also become snagged on a floating or fixed object, resulting in further entanglement, with potential loss of appendages, which may affect mobility, feeding, predator evasion, or reproduction. Observers on longliners that have captured (hooked) a turtle are directed to clip the line as close to the hook as possible in order to minimize the amount of trailing gear. This is difficult with larger turtles, such as the leatherback, which often cannot practicably be brought on board the vessel, or in inclement weather, when such action might place the observer or the vessel and its crew at risk. Turtles captured by vessels without observers may not have the line cut as close to the hook as possible because this is not required under the proposed action. With only 5 percent of longliner trips carrying observers in the Hawaii-based longline fishery, for example, there may be many sea turtles that are released with trailing gear.

c. Post-hooking survival studies - (lightly hooked v. deeply hooked)

Research has been conducted in both the Atlantic and the Pacific to estimate post-hooking survival and behavior of sea turtles captured by longline. In the Pacific, from 1997 to late 2000, a total of 49 pelagic turtles hooked by the Hawaii-based longline fishery have had satellite transmitters attached to them in order to track their location and distance traveled following the interaction. Of these 49 turtles, 15 produced no transmissions, or their transmissions lasted less than a month¹ - 11 had deeply ingested hooks (turtles had swallowed the hook, and it was not removed) and 4 were lightly hooked (turtles had the hook lodged externally (beak or flipper), permitting easy removal) (D. Parker and G. Balazs, NMFS, personal communication, November, 2000). No assumptions were made regarding the fate of these turtles that failed to transmit or only transmitted for a short period of time. Assuming that the satellite transmitter was working correctly, there are a number of possible explanations for little or no transmissions, any of which could be correct. Following the hooking incident, including the forced submergence, hauling of the longline and subsequent capture by the vessel, the released turtle may not have had time to recover from its experience. As discussed in more detail above, turtles that expend valuable amounts of energy as a result of increased activity need time at the surface to process lactic acid loads. Sea turtles often appear to be moving fairly well and then just collapse, while they rebuild their energy stores or repay their oxygen debt (E. Jacobsen, *in* Balazs, *et al.*, 1995). If a turtle does not have enough energy to remain afloat, it could submerge and die. In addition, injuries sustained as a result of the hooking incident, especially in incidents where the hook may have perforated an organ, may also result in death to the turtle. In both instances, the turtle sinks with the transmitter, and no signal is received. Whether or not these turtles were assumed to have remained submerged and

¹Of these 15 turtles, only 4 (all loggerheads) did actually produce transmissions lasting 0, 1, 6, and 13 days, traveling 13, 46, 161, and 354 kilometers, respectively. The rest (n=9) did not produce any transmissions (D. Parker and G. Balazs, NMFS, personal communication, September, 2000).

therefore died, or whether or not the transmitters failed to transmit is a matter of speculation.

For the 34 turtles that did produce successful tracks for periods lasting more than a month, there were no significant differences ($P > 0.05$) found for the duration of tracking (days) and the distance traveled between lightly hooked turtles ($n=15$) and turtles with deeply ingested hooks ($n=19$). Even when the 15 turtles that did not produce successful tracks were taken into account, no significant differences were found in terms of distance traveled and duration between the two groups (19 total lightly hooked, and 30 total deeply ingested). Furthermore, when species were analyzed individually for the two categories, no significant differences were found.

Polovina (NMFS, personal communication, September, 2000) used a contingency table approach to analyze the transmission duration in intervals of 1 month for 34 loggerheads (including those w/ few or no transmissions), comparing lightly hooked versus deeply hooked turtles. While 43% of the deeply hooked turtles transmitted less than one month compared to 27% of the lightly hooked turtles, the chi-squared test found no significant difference between the transmission distributions for these two categories. When the data for all hard shell turtles are combined ($n=48$), 22% ($n=4$) lightly hooked and 37% ($n=11$) deeply hooked turtles transmitted less than one month. Again, the difference was not statistically significant between hooking categories based on a chi-square test.

Data was also analyzed to determine whether the length of the turtle (in straight carapace length) played any role in determining differences between deeply hooked turtles and those that were lightly hooked. Only all satellite tagged loggerheads (both with successful tracks and without ($n=35$)) showed a significant difference ($P=0.02$) in size between deeply ingested (mean size = 62.0 ± 10.9 cm) and lightly hooked (mean size = 53.0 ± 6.6 cm) (D. Parker and G. Balazs, NMFS, personal communication, November, 2000).

In the eastern Atlantic, in the waters around the Azores, three juvenile loggerheads that had been lightly hooked by swordfish longline gear were instrumented with satellite-linked time-depth recorders in 1998. The number of dives performed by these hooked turtles was compared to five juvenile loggerheads that had been captured by dipnet and also instrumented. Turtles caught on longline fishing gear had significantly lower dive counts than turtle caught with dipnets during the normal (observed) period of most intense diving activity (from 9:00 am to 3:00 pm) (Bjorndal, *et al.*, 1999). During a similar study in the summer of 2000, in the same area of the Atlantic, 10 pelagic juvenile loggerheads were instrumented - four were captured with dipnets (control), and six had been deeply hooked. In all periods of the 24-hour day (separated by 6-hour increments), the hooked turtles appeared to make longer and shallower dives than control turtles, but overall, dive behavior appeared similar between hooked and non-hooked turtles, having a diurnal component (shallowest dives occurring during 21:00 and 03:00) and a seasonal component (dive depth generally increased for most turtles from summer into fall) (Riewald, *et al.*, 2000). Caution was given in interpreting both sets of data, as the studies were ongoing at the time of writing.

Given the potential for organ and tissue damage and subsequent infection, total mortalities may likely have been underestimated previously if lightly hooked animals were assigned a zero mortality rate.

NMFS has reviewed the mortality rate criteria and developed a revised estimate, described below, which takes into account the possible levels of post-interaction mortality based on these studies. This revised estimate will be used to describe the possible future impacts of the longline components of the proposed action on sea turtles. Estimates of the impacts of past interactions, which were calculated prior to NMFS' review of the mortality rates, have been left untouched.

d. Past sea turtle take in the American Samoa-based longline fishery

For the American Samoa-based longline fishery, the federal logbooks from 1992 to 1999 indicate a range of interactions with sea turtles (i.e. hooking/entanglement). In 1992, one vessel interacted with a green turtle. In 1998, one vessel interacted with an unidentified sea turtle; it was released alive. In 1999, one vessel reported interactions with four sea turtles. Three turtles released alive were recorded as a hawksbill, a leatherback, and an olive ridley. One turtle, identified as a green, was reported to have died from its interaction with this vessel. None of the species' identification were validated by the science center; and NMFS cannot attest to the local knowledge of fishermen regarding the identity of various turtle species, particularly hard-shelled turtles. However, all five species of sea turtles reportedly caught by the fishery do occur in the fishing grounds of this longline fishery. In addition, as discussed immediately below, logbook data may not be a reliable method to measure sea turtle interaction in the fisheries. Therefore, for the purposes of this Opinion, from 1992-1999, the take of sea turtles by the American Samoa-based longline fishery included at least 4 hardshelled turtles (with 3 released alive, 1 mortality), 1 leatherback, and 1 unidentified sea turtle.

e. Past estimates of sea turtle take and mortality by the Hawaii-based longline fishery

Because the bycatch information provided in skipper logbooks was considered unreliable, and due to reasonable and prudent measures listed in prior biological opinions, an observer program was established in 1994 to monitor target species caught and bycatch in the Hawaii-based longline fishery. The selection of trips to observe is based on a sampling design by DiNardo (1993) to monitor sea turtle interactions. Since February 25, 1994, observers have been placed on randomly selected trips within certain stratification categories and have recorded the number of turtle takes by species, condition of the turtles, and other potentially relevant variables such as location of the set and the interaction, environmental conditions, and types of gear and strategy used (see full description of the observer program in section II.A.1.a(1) *Observer Program for the Hawaii-based longline fishery*). Through 1999, observer coverage has ranged from 3.4% to 5.3% of annual trips (NMFS, 2000f).

“Turtle take” is defined as any interaction between a turtle and the fishing vessel or its gear, and usually implies that the turtle has become entangled in the line, or is caught on a hook. Observers complete a sea turtle life history form for every turtle observed taken by a longline vessel. Turtles are either brought aboard or sampled alongside the vessel, and from such vantage points, the observer records biological characteristics as well as the fate of the turtle. Table IV-2 contains characteristics (definitions) used by observers to define the condition and fate of turtles interacting with longline gear.

Because less than 5% of Hawaii-based longline fishing trips have been sampled since 1994, a model-

based predictor was used to estimate the total take of sea turtles by the fishery. In developing the prediction model, explanatory variables were considered in order to estimate takes accurately and precisely. Such variables included: latitude, longitude, distance to 17EC isotherm, distance to 19EC isotherm, year (1994-1999), month, day, hooks, hooks/float, temperature, catch of other species (e.g. tuna species, marlin, albatross, etc.), vessel length, and trip type (i.e. swordfish, tuna, mixed). Some of the variables considered and found to be associated with take were poorly represented in the logbooks during the time period of data gathering and were therefore not considered for prediction purposes. Table IV-3 shows the explanatory variables that were included in the prediction models for the various species of sea turtles:

Table IV-2 Definitions used to characterize the fate of sea turtles taken by Hawaii-based longliners.

Fate	Definition	Codes
Alive [Released Unharmred]	An animal removed from the fishing gear that can swim normally. The animal is likely to have minor cuts and abrasions from being entangled. This applies to entangled sea turtles only.	EOK = entangled, okay
Injured	An animal released from the fishing gear with obvious physical injury or with gear attached. An injured animal may lie at the surface, breathing irregularly, or swim in an abnormal manner. If an animal is impaled on a hook, it is considered injured. “Internal” refers to the hook being ingested, “external” implies that the turtle was hooked in the head, beak, flipper, carapace, or plastron.	HII = hooked, internal, injured HEI = hooked, external, injured HUI = hooked, unknown, injured EI = entangled, injured
Dead	An animal removed from the fishing gear in a postmortem state (i.e. the animal died due to injuries incurred during fishing operations or was returned to the sea while comatose). Animals will show a lack of muscular activity and may float passively at or below the water’s surface.	HID = hooked, internal, dead HED = hooked, external, dead HUD = hooked, unknown, dead ED = entangled, dead
Unknown	An animal lost, released, or escaped from the fishing gear whose condition was not determined.	HIU = hooked, internal, unknown; HEU = hooked, external, unknown; HUU = hooked, unknown, unknown; EU = entangled, unknown.

Table IV-3. Explanatory variables used in the prediction models

<u>Species</u>	<u>Explanatory Variables</u>	<u>Categories</u>
Green turtle	None	n/a

Leatherback	Latitude (4 categories)	lat # 14.95EN; 14.95EN < lat # 24.84EN 24.84EN lat # 33.82EN lat > 33.82EN
Loggerhead	Month (3 categories) Latitude as a polynomial Sea surface temp. (2 categories)	[1,2], [5,6], [3,4,7-12] lat + lat ² sst # 23.77EC; sst>23.77EC
Olive ridley	Sea surface temp. (2 categories)	sst # 24.22EC; sst>24.22EC

Source: McCracken, 2000.

Mortality estimates for turtles taken by the Hawaii-based longline fishery were based on limited data from Aguilar, *et al.* (1995) and from information recorded by observers on the condition of the turtles when released (Kleiber, 1998). Aguilar, *et al.* (1995) estimated a 29% mortality rate for loggerheads ingesting a longline hook; therefore all turtles (hard-shelled and leatherback) that had been hooked internally were assigned a mortality rate of 29%. Turtles recorded as dead had a 100% mortality rate, and turtles recorded as okay (released uninjured) were assigned a 0% mortality rate. All species of turtles hooked externally were also assigned a 0% mortality rate (McCracken, 2000).

Observers occasionally were unable to identify a turtle to species, or to assess their condition accurately. Therefore, identified turtles hooked in an unknown location were assigned the average mortality of the turtles of their species with a known hook location. Turtles with an unknown condition (i.e. not recorded) were assigned the average within species of turtles with condition “okay,” internally hooked, or externally hooked. For those turtles reported as hardshell with unknown hook location or unknown condition, the averaging was conducted over all turtles except leatherbacks (Kleiber, 1998), also taking into account temperature or latitude (McCracken, 2000). For example, there were 10 unidentified hardshell turtles observed taken from 1994 to 1999. The identity of these turtles was apportioned to loggerhead, olive ridley, or green turtle takes in the same proportion as observed takes of these species, and, except for green turtles, using the prediction models for each species. Based on the prediction models, olive ridley takes were higher at temperatures greater than 23.77EC, whereas loggerhead takes were higher at temperatures less than 24.22EC. If the sea surface temperature was not a clear indicator, the observed latitude was used to determine the species, since loggerhead takes were higher in the northern latitudes. In the two instances where the choice between the two species was most ambiguous, the identity was split fractionally between the three hardshelled species such that the desired proportions were acquired (McCracken, 2000).

Using the mortality rates assigned above for the condition of a turtle taken by the Hawaii-based longline fishery, the total number of turtles killed per year was estimated by averaging the mortality rates assigned to each condition class for the species, based on observed takes from 1994-1999. For example, of 147 loggerheads observed taken from 1994-1999, 83 were deeply hooked (29% mortality rate), 56 were externally hooked (0% mortality rate), 3 were hooked in an unknown location

(17% mortality rate²), 1 was dead (100% mortality rate), 3 were entangled and released alive and uninjured (0% mortality rate), and 1 was of unknown condition (17% mortality rate). Averaging these, the resultant mortality rate for the 147 loggerheads observed taken by the Hawaii-based longline fishery was 17.5% (McCracken, 2000).

Because the abundance and distribution, migration and foraging patterns, and physiology vary so significantly between the four species of sea turtles that may be encountered by longliners fishing in the Pacific Ocean, their vulnerability to the Hawaii-based longline fishing operations also varies. The following sections review the past impacts that the Hawaii-based longline fishery has had on each of the sea turtle species.

(1) Effects on green turtles: The incidental take of green turtles by the Hawaii-based longline fishery is rare. As shown in Table IV-4, observers have recorded the incidental take of 10 green turtles by the fishery from 1994-1999. All of these turtles were hooked either externally (9), or internally (1), and only one was observed dead, the rest were injured. In addition, all green turtles were taken from different trips; therefore, there was no evidence within the data that a green turtle in one set implies a higher probability of a green turtle take in another set from the same trip (McCracken, 2000).

Table IV-4. Green turtles observed taken by the Hawaii-based longline fishery from 1994-99.

Year/Fate	Condition	1994	1995	1996	1997	1998	1999	Total
Alive (Okay)	Entangled	0	0	0	0	0	0	0
Injured	Hooked, External	2	0	3	0	2	1	8
	Hooked, Internal	0	0	0	0	0	1	1
Dead	Hooked, External	0	0	0	0	0	1	1
	Hooked, Internal	0	0	0	0	0	0	0

Green turtles have been observed taken in the Hawaii-based longline fishery during the months of February through July only. The turtles were caught in the area bounded by 155EW and approximately 180EE longitude and between 5EN and 30EN latitude. Six out of the ten turtles were caught in an area around the Hawaiian island chain between 155EW and 160EW longitude and between 15EN and 30EN latitude. The remaining four were caught either far south of the Hawaiian islands (n=1), or to the northwest of the MHI (n=3) (see Figure 6 in Appendix D). In addition, more green turtles were observed taken in a swordfish-style set compared to a tuna-style set. Eight out of the ten turtles caught

²Turtles with an unknown condition were assigned the average within species of turtles with a known condition (Kleiber, 1998).

were taken in sets with less than 10 hooks per float, indicative of swordfish-style, shallow-set gear. The one mortality observed was on a deep, tuna-style set; therefore, it is likely that the turtle died as a result of its inability to reach the surface. Subadult green turtles reportedly perform routine dives of 20 meters (Brill, *et al.*, 1995, *in* Lutcavage and Lutz, 1997); therefore, it is not surprising that they are more likely to encounter a swordfish longline versus a tuna longline, which is often set below 100 meters.

Based on observer data, green turtles appear to be more likely to be hooked externally than to be entangled or hooked internally. Therefore, it is likely that green turtles may not be attracted to the baited hook or even to the lightsticks typically used during swordfish sets. The principal food sources for the green turtle are benthic marine algae. These algae are restricted to shallow depths where sunlight, substrate, and nutrients are conducive to plant growth. As a consequence, the feeding pastures used by green turtles are usually less than 10 meters deep and frequently not more than 3 meters deep, often right up to the shoreline. Because of these foraging strategies and food preferences, interactions between green turtles and the Hawaii-based longline fishery are rare.

From observer data, and using a model-based predictor, McCracken (2000) estimated that between 37 and 45 green turtles (average 40) were taken each year by the Hawaii-based longline fishery, and of these, an average of 5 were killed (given a 13% mortality rate; Table IV-5).

Table IV-5. Green turtle take and kill estimates with 95% prediction intervals (PI).

Year		1994	1995	1996	1997	1998	1999	Annual Avg
Takes	Estimate	37	38	40	38	42	45	40
	95% PI	[15-65]	[15-70]	[19-70]	[14-73]	[18-76]	[18-76]	[18-71]
Kills	Estimate	5	5	5	5	5	6	5
	95% PI	[0-16]	[0-17]	[1-17]	[0-17]	[1-19]	[1-19]	

Source: McCracken, 2000 and McCracken, personal communication, March 2001

Green turtles encountered during longline fishing may originate from a number of known proximal, or even distant, breeding colonies in the region. However the most likely candidates would include those from Hawaii (French Frigate Shoals) and the Pacific coast of Mexico population. This is based on limited genetic sampling conducted within the NMFS observer program for the Hawaii-based longline fishery. Of eight greens caught by the Hawaii-based longline fishery and genetically tested, four were of eastern Pacific (Mexico) origin, while three were either of Hawaiian origin or eastern Pacific origin, and one was of Hawaiian origin (P. Dutton, NMFS, personal communication, January, 2001). In addition, based on life history information collected by observers, green turtles encountered by the Hawaii-based longline fishery represented both subadult and adult stages. Straight carapace lengths ranged from 28.5 cm to 73.5 cm (average 51.5 cm).

(2) Effects on leatherback turtles: As shown in Table IV-6, from 1994-1999, observers recorded the incidental take of 40 leatherback turtles in the Hawaii-based longline fishery. Of these, 3 were

entangled, released alive and uninjured (7.5%), 31 were injured (77.5% – comprised of 3 entanglements, 23 hooked externally, 1 hooked internally, and 4 hooked in an unknown location), 3 died as a result of the interaction (7.5% - comprised of 2 that were entangled, and 1 that was hooked externally), and for 3 leatherbacks taken, there were no records (i.e. the observer was unable to identify the fate or condition of the turtle). Of 34 leatherbacks that had life history forms recorded by observers, only five leatherbacks were measured. Straight carapace lengths were 71, 80, 87.5, 110, and 130 centimeters. Four of these measured leatherbacks were subadults, representing early pelagic stage (n=1), and late pelagic stage (n=3), based on stage structure parameters assumed for Malaysian turtles presented in Bolten, *et al.* (1996). If the larger (130 cm) leatherback originated from the eastern Pacific, it could be an adult; otherwise, if it originated from the western Pacific, it would be a subadult (P. Dutton, NMFS, personal communication, January, 2001). Those leatherbacks that were not measured may have been too large to be safely brought on board; therefore they may have been adults.

Table IV-6. Leatherbacks observed taken by the Hawaii-based longline fishery from 1994-1999.

Year/Fate	Condition	1994	1995	1996	1997	1998	1999	Total
Alive (Okay)	Entangled	2	0	1	0	0	0	3
Injured	Entangled	0	0	2	0	1	0	3
	Hooked, External	3	3	4	10	2	1	23
	Hooked, Internal	1	0	0	0	0	0	1
	Hooked, Unknown	1	0	0	2	1	0	4
Dead	Entangled	0	0	1	0	1	0	2
	Hooked, External	0	0	0	0	0	1	1
No Record		1	1	1	0	0	0	3

Leatherback turtles have been observed taken in all months of the year, except August. The leatherbacks were caught in the area bounded by 170EE and 133EW longitude and between 5EN and 41EN latitude. Leatherbacks caught in sets above 20EN latitude (34 out of 40 leatherbacks observed) were caught in sets with less than 10 hooks per float, indicative of swordfish-style, shallow-set gear and also indicative of the general area in which swordfish-style fishing methods are used. Leatherback takes in these sets occurred primarily between 165EW and 130EW longitude and 20EN and 40EN latitude. The remaining leatherbacks observed taken (6 out of 40), were taken in sets with more than 10 hooks per float, indicative of tuna-style, deep-set gear. Leatherback takes in these sets occurred between 157EW and 167EW longitude and 5EN and 15EN latitude (see Figure 7 in Appendix D). Sea surface temperatures, latitude, and the distance to the approximate 17EC and 19EC isotherms were associated with the takes, but there was a high degree of collinearity between these variables (McCracken, 2000). When examining four latitude predictor categories for leatherbacks³, McCracken (2000) found that the proportion of sets with positive leatherback takes was higher in the northernmost and southernmost breakdown of latitudes she used, even though these areas had lower proportions of the observed sets than the middle two categories, which had high observed sets but fewer observed takes.

Leatherbacks in general appear to be very vulnerable to entanglement in fishing gear. Of 11 sea turtles examined port-mortem after being taken by a Hawaii-based longline, the only two turtles with entanglements of leaders around body parts were leatherbacks (Work, 2000). Their long pectoral flippers and their active behavior make them particularly vulnerable to any ocean debris. Studies of

³These four categories were: less than 14.95EN, between 14.95EN and 24.84EN, between 24.84EN and 33.82EN, and greater than 33.82EN (McCracken 2000).

daily swimming patterns over time yielded a very small percentage (0-7%) of time in which the leatherback was not swimming (S. Eckert, manuscript in prep. May, 2000). Leatherback hatchlings studied in captivity for almost 2 years swam persistently without ever recognizing the tank sides as a barrier (Deraniyagala, 1939, *in* Wyneken, 1997). Individual leatherbacks have been known to continue swimming while entangled in crab pot lines (Rudloe, 1979, *in* Witzell, 1984). Turtles could be captured while feeding or swimming at the surface when the longline is being set or hauled back, or when the longline is fishing at depth. A leatherback entangled by a longline will most likely continue trying to swim, expending valuable amounts of energy and oxygen. As available oxygen diminishes, anaerobic glycolysis takes over, producing high levels of lactic acid in the blood. In addition, leatherbacks store an enormous amount of oxygen in their tissues, similar to marine mammals, which is efficient for such a deep-diving turtle but means that they have relatively less oxygen available for submergence. Maximum dive duration for the species is substantially less than that of other turtles (*in* Lutcavage and Lutz, 1997). The disadvantage of this is that they are not able to hold their breath as long and are probably more vulnerable to drowning in long, longline sets.

Based on observations of all sea turtles taken by the Hawaii-based longline fishery, it appears that leatherbacks in particular tend more to get hooked externally or entangled rather than ingesting the hook. This is most likely due to their foraging strategy as well as their physiology. Whereas some hard-shelled turtle species (e.g. loggerheads) are piscivores and will forage on the bait (e.g. squid) used on longlines and therefore become hooked internally, leatherbacks tend to target cnidarians (e.g. medusae and siphonophores), so they may also be attracted to the lightsticks used on the longlines at night to attract squid and subsequently are hooked externally or entangled.

Hawaii fishermen in offshore waters see leatherbacks turtles, generally beyond the 100-fathom curve but within sight of land. Two areas where sightings take place are off the north coast of Oahu and the west coast of the Island of Hawaii, and in the area of the seamounts above the Northwestern Hawaiian Islands (*in* Skillman and Balazs, 1992). The pelagic zone surrounding the Hawaiian Islands apparently is regularly used as foraging habitat and migratory pathways for this species. Further to the north of the Hawaiian Islands, a high seas aggregation of leatherbacks is known to occur at 35EN latitude, between 175EW and 180EW longitudes (NMFS, 1991).

From observer data, and using a model-based predictor, McCracken (2000) estimated that between 88 and 132 leatherback turtles (average 112) were taken each year by the Hawaii-based longline fishery, and of these, an average of 9 were killed (given a 8% mortality rate) (Table IV-7).

Table IV-7. Leatherback turtle take and kill estimates with 95% prediction intervals (PI).

Year		1994	1995	1996	1997	1998	1999	Annual Avg
Takes	Estimate	109	99	106	88	139	132	112
	95% PI	[68-153]	[62-141]	[69-148]	[55-124]	[79-209]	[76-193]	[75-157]
Kills	Estimate	9	8	9	7	12	11	9

	95% PI	[0-22]	[0-21]	[1-21]	[0-18]	[1-28]	[1-27]	
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Source: McCracken, 2000 and McCracken, personal communication, March 2001

Based on genetic analysis of mitochondrial DNA (mtDNA), leatherback stocks encountered in the Hawaii-based longline fishery are derived from two Pacific stocks: 1) the eastern Pacific region (Mexico and Costa Rica), and 2) the western Pacific region (Malaysia, Indonesia and Solomon Islands). To date mtDNA analyses indicated that 12 of 14 leatherbacks captured in the Hawaii-based longline fishery originated from nesting populations in the southwestern Pacific; the other 2 specimens, taken in the southern range of the Hawaii fishery, were from nesting beaches in the eastern Pacific (P. Dutton, *et al.*, in press, and P. Dutton, NMFS, personal communication, May, 2000).

(3) Effects on loggerhead turtles: Of all marine turtles, loggerheads are the species most often taken by the Hawaii-based longline fishery. From 1994-99, observers recorded the incidental take of 147 loggerheads. Of these, 3 were released alive and uninjured (2%), 139 were injured by hooking (94.5%) (56 hooked externally, 83 hooked internally), and 4 died as a result of the interaction (3%) (1 hooked internally and 3 hooked in an unknown location). For one loggerhead interaction, there was no record of its condition (Table IV-8). From life history data collected by observers, it appears that the Hawaii-based longline fishery primarily interacts with juvenile loggerheads. Straight carapace lengths (SCL) ranged from 38.4 cm to 90 cm (average 56.9 cm), however, approximately 75% of the captured loggerheads were less than 65 cm SCL (G. Balazs, NMFS, personal communication, January, 2001).

Table IV-8. Loggerheads observed taken by the Hawaii-based longline fishery from 1994-1999.

Year/Fate	Condition	1994	1995	1996	1997	1998	1999	Total
Alive (Okay)	Entangled	1	1	0	1	0	0	3
Injured	Hooked, External	4	8	10	6	22	6	56
	Hooked, Internal	6	10	14	15	25	13	83
Dead	Hooked, Internal	0	0	0	0	1	0	1
	Hooked, Unknown	0	0	2	0	0	1	3
No Record		0	0	1	0	0	0	1

Figure 8 in Appendix D shows the location of loggerhead takes by the Hawaii-based longline fleet from 1994 through 1999. When loggerhead takes were analyzed statistically with several different variables (described earlier), sea surface temperature, latitude, and the distance to the approximate 17EC and 19EC isotherms were associated with the take of loggerheads, but there was a high degree of collinearity between these variables. Where both latitude and sea surface temperature were used in the

prediction model, there was a cluster of positive observations at the higher latitudes, and at these latitudes, the cluster was located in the colder temperatures. When comparing loggerhead take with latitude versus the three classifications for month (see Table IV-3 for classifications used for loggerhead), there were fewer observed trips at the higher latitudes in May and June (months 5 and 6). In fact, there were no observed takes of loggerheads during the months of May and June, and most interactions occurred during the fall and winter months, especially in January and February. Degrees of latitude appeared to be associated with the probability of loggerhead take; for example, there were no observed loggerhead takes south of 22°N (1,263 sets observed below this latitude had zero takes) (McCracken, 2000). Kleiber (1998) also found latitude to be the primary explanatory variable. In addition, out of 55 trips with positive takes of loggerheads, 29 had positive takes of loggerheads in more than one set. Therefore, it is likely that 1) loggerheads forage or migrate in groups, which is evidenced by the witnessed reports of thousands of loggerheads feeding on pelagic crabs off Baja California and/or 2) longliners target swordfish and tuna in areas of high loggerhead concentration. In the Atlantic, 68.1% of loggerheads were caught in sets with other loggerheads (31.9% caught singly), indicating that loggerheads tend to aggregate (Hoey, 1998).

All of the 147 loggerheads observed taken by the Hawaii-based longline fishery from 1994-1999 were captured by longliners targeting swordfish (i.e. target depth less than 100 meters, using less than 10 hooks per float, fishing at night, using lightsticks). The mean dive depth for loggerheads (post-nesting female and subadult) is between 9 and 22 meters; therefore, loggerheads are more likely to interact with a shallow swordfish set than a tuna set, which generally has a target depth greater than 100 meters. In addition, as described below, loggerheads tend to congregate in areas typically fished by longliners targeting swordfish, taking advantage of high productivity associated with particular oceanographic features.

Recent satellite tracking by Polovina *et al.* (2000) indicates that loggerheads of all life stages are active migrators, swimming against weak geostrophic currents along two convergent fronts as they travel from east to west across the Pacific. Of nine juvenile loggerheads tracked in the central North Pacific, six associated with a front characterized by 17°C sea surface temperature (SST) (termed “cool group”) and the other three associated with a front with a sea surface temperature of 20°C (“warm group”). Seasonally, these 17°C and 20°C isotherms move north and south over 10 degrees of latitude, and as the turtles moved westward, they also appeared to move north and south coincident with these isotherms. During the first quarter, the distribution of surface longline sets (targeting swordfish) is largely between the 17°C and 20°C SST fronts used by loggerheads. Swordfish are believed to move south through the fronts, perhaps following squid, so during the second quarter, the fishery is well to the south of the 17°C SST front but overlapping the 20°C SST front. Sea turtles tracked during the first quarter of the years (1997 and 1998) occupied waters with a mean of 17°C SST, with considerable overlap with the SST occupied by the fishery in the northern portion of the fishing grounds. As the fishery moves south in the second quarter, those “warm group” turtles following the 20°C front may be well within the fishing ground, while the “cool group” will likely be well north of the fishing ground (Polovina, *et al.*, 2000). Observer data shows that the interaction rate (turtles per longline set) is substantially greater at 17°C SST than at 20°C SST (P. Kleiber, NMFS, personal communication *in* Polovina, *et al.*, 2000).

Loggerheads in north Pacific pelagic habitats are opportunistic feeders that generally forage on items floating near or at the surface, although they will actively feed at depth if there are high densities of prey available. Loggerheads captured and killed by the international high-seas driftnet fishery in the Pacific Ocean, were opportunistically necropsied to determine stomach contents. Based on the results from 52 turtles, it appears that loggerheads are omnivorous predators of the surface layer, feeding both by swallowing floating prey whole and/or biting off prey items from larger floating objects. In samples that contained pyrosomas, the prey items often comprised a high percent of the total gut content, indicating that the turtles were encountering dense patches of this prey item. In addition, prey items normally found in the upper photic zone (within 100 meters of the surface) but not the surface layer were also found in the gut, indicating that the loggerheads actively hunted for these species (Parker, *et al.*, in press). With 57% of loggerheads observed hooked internally, it is likely that they are foraging at depth and may have been confusing lightsticks for prey items or were attracted to the baited hooks. In addition, the presence of a float in the water may have caused the initial interest and attraction to the gear.

Using mortality and take estimates described above, McCracken (2000) estimated the take and kill of loggerheads per year, as shown in Table IV-9. Of 2,505 loggerheads estimated taken by the fishery from 1994-1999, 438 were estimated killed (given a 17.5 % mortality rate).

Table IV-9. Loggerhead take and kill estimates with 95% prediction intervals (PI).

Year		1994	1995	1996	1997	1998	1999	Annual Avg
Takes	Estimate	501	412	445	371	407	369	418
	95% PI	[315-669]	[244-543]	[290-594]	[236-482]	[259-527]	[234-466]	[273-527]
Kills	Estimate	88	72	78	65	71	64	73
	95% PI	[36-141]	[31-115]	[34-127]	[28-102]	[32-112]	[28-102]	

Source: McCracken, 2000 and McCracken, personal communication, March 2001

Genetic analyses of 124 loggerheads caught in the Hawaii-based longline fishery indicated that the majority (nearly 100 percent) originated from Japanese nesting stock (Dutton, *et al.*, 1998) and the rest derived from Australia (P. Dutton, NMFS, personal communication, January, 2001).

(4) Effects on olive ridley turtles: As shown in Table IV-10, from 1994-1999, observers recorded the incidental take of 32 olive ridleys by the Hawaii-based longline fishery. Of these, 26 were injured (81% – all hooking incidents, 10 hooked externally and 16 hooked internally) and 6 died as a result of the interaction (19% - comprised of 4 that were hooked externally, and 2 that were hooked internally). In addition, of the 32 olive ridleys observed taken, 26 were captured in swordfish-style sets, and 6 were caught in tuna-style sets. Based on life history data collected by observers, it appears that the fishery is interacting with both subadult and adult life stages of olive ridleys. For those olive ridleys brought on board and measured (n=29), straight carapace length ranged from 44.5 cm to 66.5 cm (average 55.43 cm).

None of the olive ridleys observed taken by the fishery were entangled - all were hooked, 14 externally, and 16 internally; therefore, it is likely that the olive ridleys may be attracted to the baited hook or to the lightsticks, which may be confused for pyrosomas by the turtle. While the habitat of juvenile olive ridleys is not well-known, adults use a wide range of foraging habitats, feeding pelagically in deep water as well as in shallow benthic waters. They feed on a wide variety of items, ranging from jellyfish, to crabs, molluscs and algae (*in* NMFS and USFWS, 1998d). Stomach contents of 7 olive ridleys captured by the fishery were found to contain salps, cowfish and pyrosomas. One animal had seabird feathers and pelagic snails, while another had large amounts of plastic, fishing line and cellophane. Four of the olive ridleys examined had bait in their esophagus. One of these four turtles was found with three fish used as longline bait, indicating that it had ingested from more than one hook (Work and Balazs, draft manuscript, January, 2001).

Table IV-10. Olive ridleys observed taken by the Hawaii-based longline fishery from 1994-1998.

Year/Fate	Condition	1994	1995	1996	1997	1998	1999	Total
Injured	Hooked, External	2	2	2	1	1	2	10
	Hooked, Internal	1	1	6	2	1	5	16
Dead	Hooked, External	0	0	1	0	2	1	4
	Hooked, Internal	0	1	0	0	1	0	2

From 1994 to 1999, olive ridleys were observed taken by the Hawaii-based longline fishery during all months of the year except February, with most of the take occurring during the warmer months (May-August). In addition, the fishery interacted with olive ridleys throughout the fishing grounds, with observed takes ranging from as far north as 33EN to as far south as 7EN latitude, and from longitudes 143EW, west to 175EW (see Figure 9 in Appendix D). Sea surface temperatures, latitude, and the distance to the approximate 17EC and 19EC isotherms were associated with the takes, but there was a high degree of collinearity between these variables. There was a clear distinction between the proportion of takes between the two categories of sea surface temperature, but over latitude, the pattern was less clear (McCracken, 2000).

Based on observer data, olive ridleys had the highest mortality rate of all sea turtles taken by the Hawaii-based longline fishery, most likely because more olive ridleys were captured and killed in tuna-style sets than any other species of sea turtle. As shown in Table IV-11, of 878 olive ridleys estimated taken by the fishery from 1994-1999, 292 were estimated killed (given a 33.25% mortality rate). Although pathological lesions were noted in 5 olive ridleys necropsied after being taken and killed by the fishery, these were considered mild and incidental (i.e. the turtles were probably not predisposed to being taken as a result of the lesions) (Work, 2000). Therefore, the turtles that died as a result of the interaction most likely drowned, suffocated, or succumbed to injuries suffered as a result of their being hooked. Of the 6 taken by tuna-style sets, 5 died. This high mortality rate is most likely as a result of

the turtles' inability to reach the surface, due to the deep sets.

Results from genetic analyses suggest that olive ridley stocks involved in the Hawaii-based longline fishery may originate from nesting beaches in both the western and Indian Pacific, and in the eastern Pacific. Although haplotypes for olive ridley rookeries have not been identified due to small sampling sizes, there is a current effort underway to expand the rookery database. Thus far, genetic analyses suggest that of the 20 sampled olive ridleys taken by the Hawaii-based longline fishery, 40 % (n=8) originate from the Indian/western Pacific and 60% (n=12) originate from the eastern Pacific (P. Dutton, NMFS, personal communication, January, 2001). Some areas of large relative take of olive ridleys indicated representation from both eastern and western Pacific beaches, signifying that ridleys from both sides of the Pacific converge in the north Pacific pelagic environment.

Table IV-11. Olive ridley take and kill estimates with 95% prediction intervals (PI).

Year		1994	1995	1996	1997	1998	1999	Annual Avg
Takes	Estimate	107	143	153	154	157	164	146
	95% PI	[70-156]	[90-205]	[103-210]	[103-216]	[102-221]	[111-231]	[99-203]
Kills	Estimate	36	47	51	51	52	55	49
	95% PI	[8-64]	[7-84]	[11-90]	[8-92]	[11-92]	[11-96]	

Source: McCracken, 2000 and McCracken, personal communication, March 2001

d. Comparison of swordfish method and tuna method for the Hawaii-based longline fishery

Data collected by NMFS observers show that when the Hawaii-based longline vessels target swordfish or a mix of tuna and swordfish, the incidental catch of sea turtles is higher than when the vessels target tuna. One reason for this is that vessels targeting swordfish or mixed targets are more likely to operate within the foraging range of the turtles. Secondly, differences in gear configuration and the depth and time of gear deployment of swordfish and tuna-style fishing may affect the catch rate of turtles. The following discusses the differences in the gear and fishing methods of the two types of longline fishing that occur within the Hawaii-based longline fishery.

(1) Description of longline gear: Longline fishing is a passive fishing method that consists of suspending a monofilament line (main line) in the water column, by using floats, and attaching baited hooks along the line to attract fish. While the main line is deployed over the stern of the vessel, floats and hooks are attached to the main line using clips. Each float is attached to a float line and each hook is attached to a "branch line." The branch line is sometimes called a "gangion" or "dropper" line. For the most part, the branch lines are evenly spaced along the main line, except between floats where the placement of the float on the main line may lengthen the distance between the branch lines. The lengths of the branch lines and the float lines affect how deep the gear (hook) will fish and the type of species that might be caught. The depth that hooks actually fish is also determined by the vessel speed, drum speed, and shooter speed. The faster the main line is set (more line set in a shorter distance), the

deeper the line will sink because of the line sag between the floats. In addition to the speed that the main line is set, the number of hooks and the size of the weight on each branch line can affect the depth and rate that the gear will sink. The type of species that are caught are also affected by the time of day the gear is set and the type of bait that is used.

(a) *Swordfish or mixed target longline fishery*: Pacific Ocean longline vessels targeting swordfish or a mixture of tuna and swordfish, typically deploy about 42 horizontal miles of main line in the water. Most branch lines are about 17 meters (56 feet) in length and float lines are about 8 meters (26 feet) in length. For bait, fishers use squid (either large or small) and a number 9 Mustad (J-shaped) hook or, more rarely, an offset J-shaped hook. In addition, fishers use lightsticks on almost half of the hooks (every other hook). A typical set uses about 820 hooks and 189 floats which means there are approximately 4 or 5 hooks between each float. Assuming the branch lines and the float lines are evenly spaced, the distance between them is approximately 67 meters (220 feet). On average, fishers try to set their gear at about 28 meters (92 feet) below the water surface. The gear is allowed to soak during the night and soak times of the gear typically last about 20 hours, including setting and hauling of gear. This type of set is referred to below as swordfish-style gear.

(b) *Tuna longline fishery*: Tuna vessels targeting tuna in the Pacific Ocean deploy about 34 horizontal miles of main line in the water. Vessels targeting tuna typically use a line shooter. The line shooter increases the speed at which the main line is set which causes the main line to sag in the middle (more line between floats), allowing the middle hooks to fish deeper. The average speed of the shooter is 9 knots. The vessel speed is about 6.8 knots. No light sticks are used as the gear soaks. The float line length is about 22 meters (72 feet) and the branch line lengths are about 13 meters (43 feet). The average number of hooks deployed is about 1,690 hooks per set with about 27 hooks set between each float. There are approximately 66 floats used during each set. Instead of squid, tuna vessels use saury (sanma) as bait and the hook type used are “tuna” hooks. The average target depth is 167 meters. The gear is allowed to soak during the day and the total soak time typically lasts about 19 hours, including setting and hauling of gear. This type of set is referred to below as tuna-style gear.

(c) *Differences between the swordfish/mixed target and tuna fisheries*: The majority of the swordfish-style gear sets occur north of the Hawaiian Islands and the majority of tuna-style gear sets occur south of the Hawaiian Islands. Swordfish-style vessels fish shallower using fewer hooks per float than vessels targeting tuna. For practical purposes, vessels using fewer than 10 hooks per float are targeting swordfish, or a mix of swordfish and tuna, and vessels using more than 10 hooks per float are targeting tuna (D. Kobayashi, NMFS, personal communication, January, 2001). Swordfish vessels set about 42 horizontal miles of gear whereas tuna vessels set only 34 horizontal miles of gear. The shorter horizontal distance is because tuna vessels put more sag in their gear and the gear is fishing deeper even though the mainline itself may be the same length between the two types of sets. To increase the amount of sag in the main line on tuna sets, fewer floats are used with more mainline between each float, which will increase the amount of sag.

Routine dives for sea turtles range from 9-22 meters (loggerhead) to 50-84 meters (leatherback) (*in* Lutcavage and Lutz, 1997), and foraging often takes place at night in order to target vertically migrating

zooplankton (e.g. Eckert *et al.*, 1989). In addition, there is speculation that sea turtles are able to target some species due to their bioluminescence (e.g. pyrosomas). Therefore, a longline set at more shallow depths, at night, using lightsticks appears to be more likely to take turtles than one set deeper during the day.

Table IV-12. Differences between the gear and fishing methods for vessels targeting swordfish compared to vessels targeting bigeye tuna using averages derived from observer data (February 1994 - December 1999).

Gear/Trip Type	Swordfish Fishing	Tuna Fishing
Area Fished	North of Hawaiian Islands	South of Hawaiian Islands
Main line Length	42 miles	34 miles
Shooter Used	No	Yes
Vessel Speed	7.8 knots	6.8
Lightsticks Used	Yes	No
Branch Line Length	17 meters	13 meters
Float Line Length	8 meters	22 meters
Number of Hooks	820 hooks	1,690 hooks
Number of Hooks per Float	4 hooks	27 hooks
Number of Floats	189 floats	66 floats
Type of Hook	J-shaped	Tuna
Type of Bait	Squid	Saury
Target Depth	28 meters	167 meters
Gear Soaks	Night	Day
Soak Time	20 hours	19 hours

(2). Comparison of fishing method with turtle interaction rates and condition: Swordfish-style gear fishing effort rarely occurs below 20°N throughout the year (see Figures 1 through 5 in Appendix D), although there has been some concentration of effort between 18°E and 20°E N in the third quarter. Tuna-style gear fishing effort rarely occurs north of 25°N. Examination of observer data from 1994 to 1999 indicates that turtle takes on swordfish-style gear occurred throughout the area observed for this segment of the fishery (see Figures 1 and 6 through 10 in Appendix D). Conversely, the observer data set shows large areas of tuna-style fishing effort with no associated sea turtle takes (see Figures 1 and 6 through 10 in Appendix D). As discussed below, swordfish-style sets have consistently shown a higher interaction rate with all species of sea turtles compared to tuna-style sets.

From February 1994 through December 1999, 239 turtles have been observed taken by the Hawaii-based longline fishery. Of these 239, only 14 have been observed caught by tuna-style, deep-set

fishing gear out of 1,440 observed tuna-style sets (0.0097 turtles per set). Conversely, 225 turtles were observed taken in 1,811 swordfish-style sets (0.1242 turtles per set), a markedly higher interaction rate. This higher interaction rate in swordfish-style sets occurs within species as well (see above discussion in *Past estimates of sea turtle take and mortality by the Hawaii-based longline fishery*).

The condition of these 239 observed turtles is displayed in Table IV-13 below. No turtles were released alive and uninjured from tuna-style sets, compared to 6 of 225 turtles taken by swordfish sets (2.7%). This minor difference may not be significant given the large difference in interaction sample size between the two fishing methods.

It appears, based on observer data, that sea turtles caught in the two different gear types experience different rates of “immediate” mortality, or death of a turtle while still on the gear. Eight of the 14 turtles (57%), or 0.0056 turtles per set, caught by tuna-style gear were dead upon retrieval of the gear compared to three turtles (1.33%, or up to 4.9% if all unknown condition turtles are treated as dead) dead out of 225 turtles, or 0.0017 turtles per set, caught in swordfish-style gear. Differences in species-specific “immediate” mortality between gear types are also apparent. Based on past observer data for 1,440 tuna-style sets, 50% of the green turtles, 33% of the leatherback turtles, and 83% of the olive ridley turtles died per set. Loggerhead turtles were not observed captured in this segment of the fishery. In 1,811 swordfish-style gear sets, 11.8% of the leatherback turtles, 1.36% of the loggerhead turtles, 3.85% of the olive ridley turtles, and 40% of the unidentified sea turtles died per set (assuming that the 4 out of 10 turtles captured in “unknown” condition were mortalities). This difference between “immediate” death rates could have several explanations, although one possible explanation is that the turtles captured in tuna-style sets could not reach the surface to breathe or rest, but turtles caught in swordfish-style gear may be able to reach the surface. For example, on a swordfish set, the length of the branch line is 17 meters. This length is more than half the distance between the hook and the surface (average target depth is 28 meters). With a float line length of 8 meters, the main line sag between floats would be about 3 meters or about 11 meters below the water surface. This means that a hooked turtle could swim to the surface and breathe because the branch line length is greater than the depth of the main line from the surface.

Overall mortality rates, or combined immediate and delayed mortality rates, are also notably different between the two fishing styles. In tuna-style sets, five turtles were lightly hooked and one was entangled. These injuries were assigned a 0% post-interaction mortality rate (McCracken, 2000). In swordfish-style sets 108 turtles were lightly hooked, 103 were deeply hooked, and two were entangled. Deeply hooked turtles were assigned a post-interaction mortality rate of 29% (McCracken, 2000). Given the assigned mortality rates for dead and deeply hooked sea turtles, the tuna-style gear had a sea turtle mortality rate per take of 57% and the swordfish-style gear had an overall sea turtle mortality rate per take of 14.7% (30 turtles killed by deep hook injuries [29% of 103 deep hooked turtles] and 3 turtles dead upon gear retrieval [100% mortality] = 33 turtles/225 turtles = 14.7%). This appears to be a considerable difference in overall mortality rates between the two types of fishing, however when overall mortality rates are calculated per set, it becomes apparent that swordfish-style gear kills more turtles per set (0.0182 turtles per set versus 0.0056 turtles per set in tuna-style sets) due

to the higher interaction rates and higher incidence of deep hooking swordfish sets have with turtles compared to tuna sets. Revision of the kills per set data using more recent information on post-hooking delayed mortality (discussed below in Section C. *Expected Annual Impacts of Pelagics FMP Fisheries on Sea Turtles*) which assigns a 27% mortality rate to externally hooked turtles with minor or moderate injuries and a 42% mortality rate to turtles with more serious injuries, including deep hooks, still indicates that swordfish-style gear sets kill more turtles per set with 0.042 turtles killed per set compared to tuna-style gear sets which kill 0.0081 turtles per set.

D. Future Effects of Pelagics FMP Fisheries on Sea Turtles

Under the proposed action, NMFS expects that fishing effort in all fisheries under the Pelagics FMP will continue as it has in previous years, including limitations placed on the number and size of vessels in the Hawaii-based longline fishery. NMFS also anticipates that, due to the lack of measures to avoid or reduce the amount of bycatch and mortal bycatch of listed species, these interactions will continue with the same frequency and effect as they have in the past.

1. Handline, Troll, and Pole and Line Fisheries

There have been no reported interactions with sea turtles in the fisheries of the Pelagics FMP other than the Hawaii-based longline fishery, the American Samoa-based longline fishery, and the central and western Pacific U.S. purse-seine fishery (discussed below). There is a chance, based on fishing methods including bait used and gear-type, that these other fisheries do interact with sea turtles although the information is not reported. Due to low effort and target-species selectivity of the gear, incidental take and mortality in these fisheries is likely minimal and has an insignificant effect on the survival and recovery of sea turtle populations.

2. Longline Fisheries

a. American Samoa-based longline fishery

Because NMFS does not have an observer program in place for the American-Samoa-based longline fishery, the only information available is from fisher logbooks. Based on logbooks from 1992 through 1999, it is apparent that this fishery takes sea turtles, but NMFS cannot quantitatively estimate the amount or extent of take of sea turtles by this fishery. In addition, all species of listed sea turtles considered in this Opinion occur within the fishing grounds of this fishery and therefore, all of these species may be taken. Based on observed trends in the longline fleet operating out of American Samoa, it appears that effort may be increasing in this fishery. Increases in effort may result in increased levels of incidental take of sea turtles, however since NMFS has no current estimates of the amount of take that might occur in this fishery, it is impossible to speculate what take levels would be with more effort.

Table IV-13 . Disposition of turtles released based on observer data from February 1994 through December 31, 1999, stratified by less than 10 hooks per float (swordfish style fishing) and greater than or equal to 10 hooks per float (tuna style fishing).

		< 10 hooks per float (Swordfish)						≥ 10 hooks per float (Tuna)					
Species	Total	Alive	Light	Injured Deep	Entangled	Dead	Unknown	Alive	Light	Injured Deep	Entangled	Dead	Unknown
Green Turtle	10	0	7	1	0	0	0	0	1	0	0	1	0
Leatherback Turtle	40	3	24 ¹	1	2	1	3	0	3	0	1	2	0
Loggerhead Turtle	147	3	64	83	0	1	1	0	0	0	0	0	0
Olive Ridley Turtle	32	0	9	16	0	1	0	0	1	0	0	5	0
Unidentified Turtle	10	0	4 ²	2	0	0	4	0	0	0	0	0	0

¹ Exact hooking location of 4 turtles is unknown and is assumed to be lightly hooked.

² Exact hooking location of 3 turtles is unknown and is assumed to be lightly hooked.

b. *Hawaii-based longline fishery*

Based on past observer data and logbook data on the effort and distribution of the Hawaii-based longline fishery, NMFS has calculated the expected annual impact of the continued operation of this fishery (see Table IV-15 below). Expected annual capture was calculated as the 95% prediction interval ranges for each species based on the 1994 through 1999 estimates of incidental take (M. McCracken, NMFS, personal communication, March, 2001).

For estimating possible future mortality, NMFS has reviewed the results of several post-hooking survival studies. In a January 4, 2001, memorandum to the Southeast Regional Office, the Office of Protected Resources (F/PR) recommended that 50% of longline interactions with all species of sea turtles be classified as lethal, and 50% be classified as non-lethal. This finding was based on a review of several post-hooking studies in Hawaii, the eastern Atlantic, and the Mediterranean (i.e. Aguilar *et al.* (1995), Parker and Balazs (pers. comm, 2000), Bjorndal, *et al.* (1999), Riewald, *et al.* (2000)), as well as analyses of input from veterinarians and scientists with expertise in sea turtle biology and/or longline gear impacts. Knowles (2001) concluded that, based on the range of mortality reported in the various studies and adopting a “risk-averse approach that provides the benefit of doubt to the species where there are gaps in the information base,” post-interaction mortality rates of sea turtles released in the wild, under actual fishing conditions, are likely higher than those observed in scientific studies.

Upon review of this memo and the studies upon which the recommendations were based, NMFS' Office of Sustainable Fisheries and NMFS' Southwest Fisheries Science Center, Honolulu Laboratory recommended that post-hooking mortality rates applied to turtles captured by longlines reflect the differences in post-interaction survival between seriously and non-seriously injured animals found in these studies rather than apply one mortality rate across the board (Morehead, 2001; NMFS-SWFSC, 2001). In addition, the Honolulu Laboratory stated, “(e)stimates of turtle mortality, or any other quantity, should be the best estimates that we can muster and should not contain internal buffers or fudge factors of any kind. It is at the point that estimated quantities enter into making management decisions that consideration should be given to the uncertainty inherent in those estimates” (NMFS-SWFSC, 2001). After reviewing information summarized in the Knowles 2001 and Morehead 2001 memos, NMFS' derived a consensus approach for estimating sea turtle mortalities (Morehead, 2001; NMFS 2001). NMFS' final adopted approach apportions mortality in a manner consistent with the best scientific information in lieu of applying one standard across the board, while still providing the precautionary approach required for evaluating effects to listed species (NMFS, 2001). Table IV-14 details the estimated mortality rates for sea turtles captured on long line gear based on their condition.

We should also note that very little of the available data contain information on leatherback survival post-interaction. In the absence of better data on this species, NMFS is using the best available scientific data as estimates of the mortality rates leatherbacks may experience while anticipating that more information is likely to become available in the future.

Based on these latter recommendations which take into account the best available scientific and commercial data, NMFS will apply the mortality rates in Table IV-14 to its estimates of impacts to sea

turtles captured by longline gear in the future. Uncertainty in these impact estimates as a result of differences in the handling of captured turtles or the small sample sizes upon which these mortality rates are drawn should be noted when drawing conclusions about the magnitude of the impacts of delayed mortality on sea turtle populations.

Table IV-14. Sea turtle mortality rates based on level and type of interaction with longline fishing gear. Source: Morehead, 2001; NMFS, 2001

Interaction	Response	Injury	Mortality Rate
Entangled / no hook	Disentangled	No injury	0%
Entangled / external hook	Disentangled, no gear	Minor	27%
	Disentangled, trailing gear	Moderate	27%
	Dehooked, no gear	Minor	27%
Hooked in beak or mouth	Hook left, no gear	Moderate	27%
	Hook left, trailing gear	Serious	42%
	Dehooked, no gear	Moderate	27%
Hook swallowed	Hook left, no gear	Serious	42%
	Hook left, trailing gear	Serious	42%
Turtle Retrieved Dead	- - -	Lethal	100%

Table IV-15. Rough estimates of annual capture and mortality for sea turtles taken in the Hawaii-based longline fishery.¹

Species	Incidental Take ²	Incidental Mortality ³
Green	18-71	7 - 26
Leatherback	75-157	28 - 57
Loggerhead	273-527	102 - 195
Olive Ridley	99-203	48 - 98

¹ Where numbers represented fractions of turtles, the number was rounded up to represent a whole turtle. Where condition of a turtle was marked as “unknown” NMFS assumed that the turtle had died. “Entangled” turtles, because they were not recorded as “alive and uninjured” were assigned a mortality rate of 27%.

² The upper and lower bounds of the 95% prediction intervals for the annual average take in the 1994 through 1999 fishery (See Tables IV-5, 7, 9, and 11).

³ The estimated incidental mortality is a subset of the estimated incidental take by hooking or entanglement.

We calculated expected annual mortality by applying the estimated mortality rates (described in Morehead (2001) and NMFS (2001) and presented in Table IV-14) to the proportion of animals externally hooked, deeply hooked, or retrieved dead based on past observations. For example, of the 10 green turtles observed in the Hawaii-based longline fishery (tuna-style and swordfish-style gear combined) 10% experienced immediate mortality (100% mortality rate), 80% were externally hooked (broadly estimated as 27% mortality rate), and 10% were deeply hooked (42% mortality rate). Applying these percentages and their associated mortality rate to the annual estimated range of incidental take of green turtles, NMFS calculated that 7 to 26 green turtles could be killed each year.

These ranges provide a rough estimate of the numbers of turtles that may be taken by the Hawaii-based longline fishery during any given year depending on effort and natural variation in ocean conditions and turtle abundance and use of the action area. As mentioned above, these numbers do not include uncertainty associated with small sample size in the scientific studies or differences in handling of captured turtles between scientific studies and fishing operations. In addition, these numbers are based on the effort in the fishery over the past 6 years. During those six years, the number of vessels participating in each segment of the fishery has decreased, the number of trips in the swordfish and mixed target segment has declined, and the number of trips in the tuna segment has increased. However, in all segments of the fishery the numbers of hooks in the water per set has increased. This increase is particularly evident in the tuna segment of the Hawaii-based longline fishery where the number of hooks per set in 1994 was 12,324 and 19,845 per set in 1999. An increasing trend in effort as demonstrated by more sets or hooks in the water could result in levels of incidental take and associated mortality that are higher than the numbers given above. For these reasons, NMFS' analysis of the future effects of the Hawaii-based longline component of the fisheries operating under the Pelagics FMP will use the upper bounds of the ranges given below when assessing annual and aggregate effects on the species (see section VI. *Species' Responses to the Proposed Action* below.)

V. CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this Opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Most of the fisheries described as occurring within the action area (Section III. Status of the Species and Environmental Baseline), are expected to continue as described into the foreseeable future. Therefore, NMFS is not aware of any proposed or anticipated changes in most of these fisheries that would substantially change the impacts each fishery has on the sea turtles covered by this Opinion. Numbers of vessels participating in the California longline fishery, however, appear to be increasing due to an influx of Hawaii-based longliners targeting swordfish in waters beyond 200 nm off the California coast; some of these vessels have de-registered from their Hawaii limited entry permits. Longline vessels began landing swordfish at San Pedro/Terminal Island, California in 1999. That year, 1.5 million pounds of swordfish were landed by drift gillnet and longline vessels, compared with approximately 340,000 pounds landed by just drift gillnet vessels the previous year. Longline and drift

gill net vessels landed a total of 2.6 million pounds of swordfish at San Pedro/Terminal Island, California in 2000 (D. Petersen, NMFS, personal communication, February, 2001). As a result of this increased effort off of California, interactions between listed species commonly found in northeastern portions of the action area and the California longline fishery may increase. Based on observer data in the Hawaii-based longline fishery and the California drift gillnet fishery, both leatherback and loggerhead sea turtles are commonly found in this area. Because the California longline fishery is not observed, the current level of incidental take of listed sea turtles is unknown, but may increase as a result of increased effort.

In addition to fisheries, NMFS is not aware of any proposed or anticipated changes in other human-related actions (e.g. poaching, habitat degradation) or natural conditions (e.g. over-abundance of land or sea predators, changes in oceanic conditions, etc.) that would substantially change the impacts that each threat has on the sea turtles covered by this Opinion. Therefore, NMFS expects that the levels of take of sea turtles described for each of the fisheries, except the California longline fishery, and non-fisheries will continue at similar levels into the foreseeable future.

VI. SPECIES' RESPONSE TO THE PROPOSED ACTION

The *Approach to the Assessment* section of this Opinion (page 80) stated that we approach jeopardy analyses in three steps. First, we identify the probable direct and indirect effects of an action on the physical, chemical, and biotic environment of the action area. The second step of our analysis determines if we would reasonably expect threatened or endangered species to experience reductions in reproduction, numbers, or distribution in response to these effects. The third step of our analyses, we determine if any reductions in a species' reproduction, numbers, or distribution (identified in the second step of our analysis) can be expected to appreciably reduce a listed species' likelihood of surviving and recovering in the wild.

In the *Status of the Species and Environmental Baseline* sections of this Opinion, we discussed the various natural and human-related phenomena that caused populations of the various sea turtle species to become threatened or endangered and continue to keep their populations suppressed.

This section of an Opinion examines the physical, chemical, and biotic effects of the fisheries associated with the Pelagics FMP to determine (a) if those effects can be expected to reduce the reproduction, numbers, or distribution of threatened or endangered species in the action area, (b) determine if any reductions in reproduction, numbers, or distribution would be expected to reduce the species' likelihood of surviving and recovering in the wild, and (c) if a reductions in a species' likelihood of surviving and recovering in the wild would be appreciable. For the purposes of this analysis, we will assume that anything that places sea turtle populations in the Pacific Ocean at greater risk of extinction, also places the entire species at a greater risk of extinction.

A. Green Turtles

The proposed U.S. pelagic fisheries in the western Pacific Ocean will capture, injure, or kill adult and

subadult green sea turtles. Virtually all of the green turtles that would be harmed incidental to the prosecution of fisheries under the Pelagics FMP are affected by the longline fisheries (the number of green turtles adversely affected by other fisheries included in this FMP are expected to be minimal – if any takes occur at all). Based on past patterns of green turtles captured in the longline fishery, turtles would be taken throughout the year.

The Hawaii-based longline fishery is expected to capture between 18 and 71 adult or sub-adult green turtles each year. Most of these turtles will probably be hooked, rather than entangled, with most of them hooked externally; external hooking is expected to kill fewer turtles than internal hooking. Between 7 and 26 of the green turtles captured in this fishery are expected to die each year as a result of the interaction. In the past, swordfish or mixed target-style gear has had a higher interaction rate of captures (0.0044 green turtles per set) and subsequent injuries and deaths of green turtles than tuna-style gear (0.0014 turtles per set); we expect this pattern to continue.

If the Hawaii-based longline fishery affects green turtle populations proportional to their relative abundance in the action area, about half of the green turtles that are captured, injured, or killed by the longline fisheries would come from the eastern Pacific population that nests in Mexico. Another 35 percent of the affected turtles would represent either the eastern Pacific population or the Hawaiian population, and the remaining 12 percent would represent the Hawaiian population. Using this assumption, it is reasonable to expect between 13 and 23 adult or sub-adult green turtles from the eastern Pacific population and between 3 and 13 adult or sub-adult green turtles from the Hawaiian population each year would be killed each year in the longline fishery. Further, it would be reasonable to expect that more of these green turtles would be taken by the swordfish/mixed target component of the fishery based on that component's higher interaction rates.

We believe it is reasonable to expect that killing up to 26 adult or sub-adult green turtles each year would reduce the numbers of individuals in the species, particularly since population estimates for this species are based on estimated numbers of adult turtles. Assuming that some of these turtles would be female, we would also conclude that these deaths would reduce the species' reproduction in addition to reducing their numbers. Assuming that turtles captured and killed in the fishery are proportional to their relative abundance in the action area, the western Pacific population of green turtles would experience the larger reduction in reproduction and numbers.

We also believe it is reasonable to expect that these mortalities will appreciably reduce the green sea turtles' likelihood of surviving and recovering in the wild, particularly given the status and trend of green turtle populations in the Pacific basin. Although specific data on green turtle populations in the Pacific islands are limited, the available data suggest they have declined dramatically because of egg harvests and adults killed by humans. For example, the recovery plan for the green turtle identifies harvests of eggs and adult turtles as a "major problem" in American Samoa, Guam, Palau, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, the Republic of the Marshall Islands, and the Unincorporated Islands (Wake, Johnston, Kingman, Palmyra, Jarvis, Howland, Baker, and Midway) (NMFS and USFWS, 1998a).

In the *Environmental Baseline* section of this Opinion, we noted that green turtles are captured, injured, or killed in numerous Pacific fisheries including Japanese longline fisheries in the western Pacific Ocean and South China Seas; longline fisheries off the Federated States of Micronesia; commercial and artisanal swordfish fisheries off Chile, Columbia, Ecuador, and Peru; purse seine fisheries for tuna in the eastern tropical Pacific Ocean, and California/Oregon drift gillnet fisheries. Because of limited available data, we cannot accurately estimate the number of green turtles captured, injured, or killed through interactions with these fisheries. However, an estimated 85 green turtles were estimated to have died between 1993 and 1997 in interactions with the tuna purse seine fishery in the eastern tropical Pacific Ocean; approximately 7,800 green turtles are estimated to die annually in fisheries and direct harvest off of Baja, California; and before 1992, the North Pacific driftnet fisheries for squid, tuna, and billfish captured an estimated 378 green turtles each year, killing about 93 of them each year. Little data on the life stage or sex of captured animals is available; however, it is reasonable to expect that both incidental and intentional takes affect the larger turtle life stages, sub-adults and adults.

Removing adult or sub-adult green turtles from the adult population in these numbers reduces the abundance of the overall population in a way that would also reduce their reproductive success. These mortality levels, on top of human-induced pressures on nesting beaches, would contribute to, or exacerbate, the precipitous declines of green turtle populations in the western and eastern Pacific Ocean.

In Mexico, green turtles were widespread and abundant prior to commercial exploitation and uncontrolled subsistence harvest of nesters and eggs. More than 165,000 turtles were harvested from 1965 to 1977 in the Mexican Pacific. In the early 1970s nearly 100,000 eggs per night were collected from these nesting beaches (NMFS and USFWS, 1998a). Although the number of adult female green turtles killed by poachers in Mexico has been reduced dramatically, the number of nests destroyed for the black market for sea turtle eggs has not changed significantly since the ban (Delgado and Alvarado, 1999).

Despite attempts at long-term protection of females and their eggs at nesting sites since 1990, the population continues to decline. At Colola, the beach responsible for 70% of the green turtles that nest in Michoacán (Delgado and Alverado, 1999), counts in the early 1990s found an estimated 60-100 females nesting per night, or about 800-1,000 turtles per year (Eckert, 1993). During the 1998-99 season, an estimated 600 greens nested at Colola (Delgado and Alverado, 1999). Previously, the nesting population at the two main nesting beaches in Michoacán, Mexico, was estimated as 5,585 females in 1982 and 940 in 1984. Then, during the 1990's, Delgado and Alverado (1999) estimated female nester abundance at Michoacán as ranging between approximately 250 and 1,200 female turtles per year, suggesting that the population is experiencing dramatic swings in abundance which, over time, has and could continue to result in extremely small or even extirpated populations in some years. Researchers believe the numbers of adult green turtles incidentally captured and killed in various coastal fisheries and those intentionally killed in coastal foraging areas prevents this population from increasing (P. Dutton, NMFS, personal communication, 1999; W. Nichols, Univ. of Arizona, personal communication, 2000).

The green turtles in Hawaii are genetically-distinct and geographically isolated from other green turtle populations; therefore, they can be treated as a discrete subpopulation. Ninety percent of the nesting and breeding activity of the Hawaiian green turtle occurs at French Frigate Shoals, where 200-700 females were estimated to nest annually (NMFS and USFWS, 1998a).

Since the green turtles in Hawaii were first protected in the early 1970s, ending years of exploitation, the nesting population of green turtles in Hawaii has shown a gradual but definite increase (Balazs, 1996). For example, the number of green turtles nesting at an index study site at East Island has tripled since systematic monitoring began in 1973 (NMFS and USFWS, 1998a). Nevertheless, the small size and geographic isolation of this population makes it vulnerable to changes caused by reduced birth rates, increased death rates, or both. The incidence of diseases such as fibropapilloma, and spirochidiasis, which are major causes of strandings of green turtles suggests that future declines in this population could reverse or eliminate the increases of recent decades (Murakawa *et al.*, 2000).

As discussed previously, the eastern Pacific population of green turtles is declining due to a combination of high egg mortalities on nesting beaches and high adult and sub-adult deaths in coastal fisheries and direct harvests. In effect, this population is declining because the number of sub-adults that survive to recruit into the adult population does not offset the number of adults that die in the same time interval. The loss of an additional 13 to 23 adult or sub-adult, green turtles from this population each year would reduce the number of adult turtles that reproduce each year which, in turn, would have long-term effects on the size of this green turtle population.

For example, in the time it would take the survivors of the 2001 cohort of eggs to recruit into the adult, breeding population (approximately 25 years), between 325 and 575 adult or sub-adult green turtles would have been killed in interactions with the longline component of the Pelagic fisheries, if projected death rates remained constant. If the 13 to 23 eastern Pacific adult or sub-adult green turtles captured and killed in this fishery each year *are* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery would not reduce the green turtle's likelihood of surviving or recovering in the wild. On the other hand, if the 13 to 23 eastern Pacific adult or sub-adult green turtles captured and killed in this fishery each year *are not* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery could threaten this population's likelihood of surviving and recovering in the wild.

Unfortunately, we do not have enough information on the age structure of this population or age-specific survival rates to determine which of these two scenarios is more likely. However, the declining status and trend of this population, as a result of high mortalities in all life stages from poaching, habitat development, and incidental and intentional mortality in fisheries, suggests that dying adults and sub-adults in this population are not replaced by equal numbers of maturing juveniles and sub-adults. Therefore, we will assume the 13 to 23 eastern Pacific adult or sub-adult green turtles captured and killed in this fishery each year *will not* be replaced in the same time interval by equal or greater numbers of maturing turtles.

With this assumption, as many as 575 adult green turtles will be permanently removed from the eastern

Pacific population of green turtles over the next 25 years. Removing these numbers of reproductive adults and pre-reproductive sub-adults from this declining population would be expected to reduce the reproductive success of the eastern Pacific populations, which would, in turn, reduce or eliminate this population's ability to recover from its high rate of decline. This would appreciably diminish this population's likelihood of surviving in the wild, although we cannot quantify the exact magnitude of this effect. Given the current abundance of nesting females at major eastern Pacific beaches, if the Pelagics FMP fisheries were the only fisheries taking green turtles during this period, this impact alone could have serious consequences for the survival and recovery of the eastern Pacific green turtle population. Given the small size of this population, this would appreciably reduce the population's size and reproductive capacity to a degree that would appreciably increase this population's risk of extinction.

The Hawaiian population of green turtles would be affected to a lesser degree, although between 75 and 325 adult and sub-adult green turtles would be killed in the fishery in the time it would take eggs from the 2001 cohort to recruit into the adult, breeding population. Although this population has been increase slowly, we do not know how this level of adult or sub-adult mortality would affect this population's status or trend. The isolation and genetic distinctness of this population, combined with a high incidence of often fatal fibropapilloma, predisposes the Hawaiian population to a higher risk of extinction. It is reasonable to expect that compounding this higher risk of extinction with adult and sub-adult mortalities from Pelagic fisheries would appreciably reduce the Hawaiian population's likelihood of survival and recovery in the wild.

The potential loss of the eastern Pacific population and the Hawaiian population of green turtles would represent a dramatic reduction in the species' distribution, abundance, and reproduction by eliminating a number of populations, reducing genetic diversity and viability, representation of critical life stages, total population abundance, and resilience as small sub-populations are extirpated, thereby appreciably reducing the likelihood of the survival and recovery of green turtles in the wild.

B. Leatherback Turtles

The proposed U.S. pelagic fisheries in the western Pacific Ocean will capture, injure, or kill adult and subadult leatherback sea turtles. Virtually all of the leatherback turtles that would be harmed incidental to the prosecution of fisheries under the Pelagics FMP are affected by the longline fisheries (the number of leatherback turtles adversely affected by other fisheries included in this FMP are expected to be minimal – if any takes occur at all). Based on past patterns of leatherback turtles captured in the longline fishery, turtles may be taken throughout the year, primarily between 130EW and 165EW longitude and between 20EN and 40E N latitude.

Based on past patterns, the Hawaii-based longline fishery are expected to capture between 75 and 157 adult or sub-adult leatherback turtles each year. Most of these turtles will probably be hooked, rather than entangled, with most of them being hooked externally (external hooking is expected to kill fewer turtles than internal hooking). Nevertheless, between 28 and 57 of the leatherback turtles captured in this fishery are expected to die each year from their interaction with the fishery. In the past, swordfish or mixed target-style gear has had a higher rate of captures (0.0188 leatherback turtles per set) and

subsequent injuries and deaths of leatherback turtles than tuna-style gear (0.0042 turtles per set). Because the fishing methods used in the fishery, ocean currents, and the migratory patterns of sea turtles appear to be analogous to previous patterns, we expect the number of turtles that interact with the fishery to continue as well.

The limited genetic sampling from the area indicates that about 86% of the leatherback turtle sample (12 out of 14 genetic samples) originated from western Pacific nesting beaches (P. Dutton *et al.*, 2000; P. Dutton, NMFS, personal communication, January, 2001). If the longline fisheries affect leatherback turtle populations proportional to their relative abundance in the action area (as documented through observer data), about 86 percent of the leatherback turtles that are captured, injured, or killed by the longline fisheries would come from the western Pacific populations. The remaining 14 percent would represent the eastern Pacific population. Assuming proportionality, between 24 and 49 adult or sub-adult leatherback turtles from the western Pacific population and between 4 and 8 turtles from the eastern Pacific population would be killed in the Hawaii-based longline fishery each year. Further, we expect the swordfish/mixed-target component of the fishery would capture and kill more of these leatherback turtles based on that component's higher interaction rates.

We believe it is reasonable to expect that killing up to 57 adult or sub-adult leatherback turtles each year would reduce the numbers of individuals in the species, particularly since population estimates for this species are based on estimated numbers of adult turtles. Assuming that some of these turtles would be female, we would also conclude that these deaths would reduce the species' reproduction in addition to reducing their numbers. Assuming that turtles captured and killed in the fishery are proportional to their relative abundance in the action area, the western Pacific population of leatherback turtles would experience the larger reduction in reproduction and numbers.

We also believe it is reasonable to expect that these mortalities will appreciably reduce the leatherback sea turtles' likelihood of surviving and recovering in the wild, particularly given the status and trend of leatherback turtle populations in the Pacific basin. Based on published estimates of nesting female abundance, leatherback populations have collapsed or have been declining at all major Pacific basin nesting beaches for the last two decades (Spotila *et al.*, 1996; NMFS and USFWS 1998b; Sarti, *et al.* 2000; Spotila, *et al.* 2000). Leatherback turtles had disappeared from India before 1930, have been virtually extinct in Sri Lanka since 1994, and appear to be approaching extinction in Malaysia (Spotila *et al.* 2000).

In the western Pacific Ocean, declines in leatherback nesting assemblages have been documented by systematic beach counts or surveys in Rantau Abang, Terengganu (Malaysia). The nesting assemblage Terengganu - which was one of the most significant nesting sites in the western Pacific Ocean - has declined severely from an estimated 3,103 females in 1968 to 2 nesting females in 1994 (Chan and Liew, 1996; see also Table III-2). The size of the current nesting assemblage represents less than 2 percent of the size of the assemblage reported from the 1950s; with one or two females nesting in this area each year (P. Dutton, personal communication, 2000). Nesting assemblages of leatherback turtles along the coasts of the Solomon Islands, which supported important nesting assemblages historically, are also reported to be declining (D. Broderick, personal communication, *in* Dutton *et al.* 1999). In

Fiji, Thailand, Australia, and Papua-New Guinea (East Papua), leatherback turtles have only been known to nest in low densities and scattered colonies.

Only an Indonesian nesting assemblage has remained relatively abundant in the Pacific basin. The largest, extant leatherback nesting assemblage in the Indo-Pacific lies on the north Vogelkop coast of Irian Jaya (West Papua), Indonesia, with over 1,000 nesting females during the 1996 season (Suarez *et al.* in press; see Table III-3). During the early-to-mid 1980s, the number of female leatherback turtles nesting on the two primary beaches of Irian Jaya appeared to be stable. More recently, however, this population has come under increasing threats that could cause this population to experience a collapse that is similar to what occurred at Terengganu, Malaysia. In 1999, for example, local Indonesian villagers started reporting dramatic declines in sea turtle populations near their villages (Suarez 1999); unless hatchling and adult turtles on nesting beaches receive more protection, this population will continue to decline. Declines in nesting assemblages of leatherback turtles have been reported throughout the western Pacific region where observers report that nesting assemblages are well below abundance levels that were observed several decades ago (for example, Suarez 1999).

In the western Pacific Ocean and South China Seas, leatherback turtles are captured, injured, or killed in numerous fisheries including Japanese longline fisheries. Leatherback turtles in the western Pacific are also threatened by poaching of eggs, killing of nesting females, human encroachment on nesting beaches, incidental capture in fishing gear, beach erosion, and egg predation by animals.

In the eastern Pacific Ocean, nesting populations of leatherback turtles are declining along the Pacific coast of Mexico and Costa Rica. According to reports from the late 1970s and early 1980s, three beaches located on the Pacific coast of Mexico support as many as half of all leatherback turtle nests. Since the early 1980s, the eastern Pacific Mexican population of adult female leatherback turtles has declined to slightly more than 200 during 1998-99 and 1999-2000 (Sarti *et al.* 2000). Spotila *et al.* (2000) reported the decline of the leatherback turtle population at Playa Grande, Costa Rica, which had been the fourth largest nesting colony in the world. Between 1988 and 1999, the nesting colony declined from 1,367 to 117 female leatherback turtles. Based on their models, Spotila *et al.* (2000) estimated that the colony could fall to less than 50 females by 2003-2004.

In the eastern Pacific Ocean, leatherback turtles are captured, injured, or killed in commercial and artisanal swordfish fisheries off Chile, Columbia, Ecuador, and Peru; purse seine fisheries for tuna in the eastern tropical Pacific Ocean, and California/Oregon drift gillnet fisheries. Because of the limited available data, we cannot accurately estimate the number of leatherback turtles captured, injured, or killed through interactions with these fisheries. However, between 8 and 17 leatherback turtles were estimated to have died annually between 1990 and 2000 in interactions with the California/ Oregon drift gillnet fishery; 500 leatherback turtles are estimated to die annually in Chilean and Peruvian fisheries; 200 leatherback turtles are estimated to die in direct harvests in Indonesia; and before 1992, the North Pacific driftnet fisheries for squid, tuna, and billfish captured an estimated 1,002 leatherback turtles each year, killing about 111 of them each year. Little data on the life stage or sex of animals captured in these fisheries are available; however, the fisheries probably affect the larger turtle life stages, sub-adults and adults because of their distribution in the ocean and the size of the animals that interact with the gear

used in the fisheries.

Although all causes of the declines in leatherback turtle colonies have not been documented, Sarti *et al.* (1998) suggest that the decline results from egg poaching, adult and sub-adult mortalities incidental to high seas fisheries, and natural fluctuations due to changing environmental conditions. Some published reports support this suggestion: (Sarti, *et al.* (2000) reported that female leatherback turtles have been killed for meat on nesting beaches like Piedra de Tiacoyunque, Guerrero, Mexico. Eckert (1997) reported that swordfish gillnet fisheries in Peru and Chile contributed to the decline of leatherback turtles in the eastern Pacific. The decline in the nesting population at Mexiquillo, Mexico occurred at the same time that effort doubled in the Chilean driftnet fishery. In response to these effects, the eastern Pacific population has continued to decline, leading some researchers to conclude that the leatherback are on the verge of extinction in the Pacific Ocean (e.g. Spotila *et al.* 1996; Spotila, *et al.* 2000).

In summary, the abundance of leatherback turtles on nesting colonies throughout the Pacific basin have declined dramatically over the past 10 to 20 years. Leatherback turtle colonies throughout the eastern and western Pacific Ocean have been reduced to a fraction of their former abundance by the combined effects of human activities that have reduced the number of nesting females and reduced the reproductive success of females that manage to nest (for example, egg poaching). At current rates of decline, leatherback turtles in the Pacific basin are a critically endangered species with a low probability of surviving and recovering in the wild.

As we discussed in the *Status of the Species* and *Approach to the Assessment* sections of this Opinion, changes in the survival of adult and sub-adult stages of leatherback turtles can have the most significant, short-term effects on the status and trend of these turtle populations (Crouse, 1999; Heppell, 1999; Caswell, 2001). The U.S. Pacific pelagic fisheries represents an additional source of mortality in leatherback turtles, particularly adult and sub-adult leatherback turtles.

As discussed previously, from the decline of the western Pacific population of leatherback turtles we infer that the rate at which sub-adult females are recruiting into the adult, breeding population is lower than the death rate of breeding, adult females (that is, adult females are dying without replacing themselves). In areas like Terengganu, the difference between recruitment rates and adult death rates would have to be dramatic to explain the declines of nesting colonies. The loss of an additional 24 to 49 adult or sub-adult, leatherback turtles from the western Pacific population each year would exacerbate the decline of this population by reducing the number of adult turtles that reproduce each year which, in turn, reduces the number of young the population can produce in a year. The loss of these adult turtles would have a short-term effect on the number of breeding adults in this leatherback population (which is already declining) and short- and long-term effects on the birth rates of this population, which will have longer-term effects on the number of breeding adults.

The cumulative, long-term effects of these losses are easier to contemplate. In the time it would take the survivors of the 2001 cohort of eggs to recruit into the adult, breeding population (approximately 9 years), up to 441 adult or sub-adult leatherback turtles would have been killed in interactions with the longline component of the Pelagic fisheries, if projected death rates remain constant. If the 24 to 49

western Pacific adult or sub-adult leatherback turtles captured and killed in this fishery each year *are* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery should not appreciably affect the leatherback turtle's likelihood of surviving or recovering in the wild. On the other hand, if the 49 western Pacific adult or sub-adult leatherback turtles captured and killed in this fishery each year *are not* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery could threaten this population's likelihood of surviving and recovering in the wild. Unfortunately, we do not have enough information on the age structure of this population or age-specific survival rates to determine which of these two scenarios is more likely. However, the declining status and trend of this population, as a result of high mortalities in all life stages from poaching, habitat development, and incidental and intentional mortality in fisheries, suggests that dying adults and sub-adults in this population are not currently being replaced by equal numbers of maturing juveniles and sub-adults.

Therefore, if the 24 to 49 western Pacific adult or sub-adult leatherback turtles captured and killed in this fishery each year *are not* replaced in the same time interval by equal or greater numbers of maturing turtles, as many as 441 adult leatherback turtles will have been permanently removed from the western Pacific population within the next 9 years. Removing these numbers of reproductive adults and pre-reproductive sub-adults from this declining population, would be expected to reduce the reproductive success of the western Pacific populations, which would, in turn, reduce or eliminate this population's ability to recover from its high rate of decline. This would appreciably diminish this population's likelihood of surviving in the wild, although we cannot quantify the exact magnitude of this effect. Given the current abundance of nesting females at major western Pacific beaches, if the Pelagics FMP fisheries were the only fisheries taking leatherback turtles during this period, this impact alone could have serious consequences for the survival and recovery of the western Pacific leatherback turtle population. Given the small size of this population, this is an appreciable reduction in the population size and reproductive capacity that would be expected to appreciably increase this population's risk of extinction.

In other biological opinions on fisheries in the Pacific Ocean, NMFS concluded that any additional reductions in the size of the western Pacific leatherback populations of leatherback turtles are likely to maintain or exacerbate the decline of these populations (e.g., NMFS, 2000d). This would further hinder population persistence or attempts at recovery as long as mortalities exceed any possible population growth, which appears to be the current case, appreciably reducing the likelihood that western Pacific leatherback populations will persist.

The eastern Pacific population of leatherback turtles would be affected to a lesser degree, although the effect would be no less significant given the depressed status of leatherback turtles in the eastern Pacific Ocean. The collapse of leatherback turtle nesting colonies along the Pacific coast of Mexico and Costa Rica over the past decade also suggests that adult, female leatherback turtles are not replacing themselves and the mortality rate of adult females is significantly higher than the recruitment rate of sub-adults. With an estimated population of about 3,000 adult females that are threatened by poaching and death in numerous fisheries, the additional loss of 4 to 8 adults would represent a chronic source of mortality and reduced fecundity that can be expected to reduce the population's likelihood of surviving

and recovering in the wild.

For example, up to 72 adult and sub-adult leatherback turtles would be killed in the fishery in the time it would take eggs from the 2001 cohort to recruit into the adult, breeding population. Removing these numbers of reproductive adults and pre-reproductive sub-adults from this declining population, would be expected to reduce the reproductive success of the eastern Pacific populations, which would, in turn, reduce or eliminate this population's ability to recover from its decline. This would appreciably diminish this population's likelihood of surviving in the wild, although we cannot quantify the magnitude of this effect. Given the small size of this population, this is likely an appreciable reduction in the population size and reproductive capacity that would be expected to appreciably increase this population's risk of extinction.

C. Loggerhead Turtles

The proposed U.S. pelagic fisheries in the western Pacific Ocean will capture, injure, or kill juvenile and subadult loggerhead sea turtles. Thus far, all of the loggerhead turtles that would be harmed incidental to the prosecution of fisheries under the Pelagics FMP are affected by the longline fisheries, specifically the swordfish/mixed target component of the fishery (the number of loggerhead turtles adversely affected by other fisheries included in this FMP are expected to be minimal – if any takes occur at all). However, since there is little data on the amount and condition of turtle bycatch in these other fisheries, NMFS cannot confidently describe the impacts of these non-longline fisheries on the *populations* of loggerhead turtles as minimal.

Based on past patterns of loggerheads captured in the Hawaii-based longline fishery, these turtles may be taken throughout the year although most interactions have occurred during the fall and winter months, especially in January and February. Geographical distribution appears to significantly affect the probability of loggerhead take; for example, there were no observed loggerhead takes south of 22°N (1,263 sets observed below this latitude had zero takes) (McCracken, 2000), and this pattern is likely to continue. In addition, loggerhead takes also appear to be correlated with sea surface temperatures (SST) as satellite telemetry data indicate that loggerheads are following 17°E and 20°E temperature fronts which swordfish also utilize. Observer data shows that the interaction rate (turtles per longline set) is substantially greater at 17°E SST than at 20°E SST (P. Kleiber, NMFS, personal communication in Polovina, *et al.*, 2000).

Based on past patterns, the Hawaii-based longline fishery are expected to capture between 273 and 527 loggerhead turtles per year. Of these turtles, between 102 and 195 are expected to die each year as a result of the interaction. Based on past observed takes, captured turtles are more likely to be internally hooked, which is assumed to have a lower survival rate than turtles hooked externally. Because the fishing methods used in the fishery, ocean currents, and the migratory patterns of sea turtles appear to be analogous to previous patterns, we expect the number of turtles that interact with the fishery to continue as well.

If the longline fisheries affect loggerhead turtle populations proportional to their relative abundance in

the action area (as documented through observer data), virtually all of the loggerhead turtles that are captured, injured, or killed by the longline fisheries come from the Japanese nesting population. Genetic analyses of 124 loggerheads caught in the Hawaii-based longline fishery indicated that the majority (nearly 100 percent) originated from Japanese nesting population and the rest originated in Australia (Dutton, *et al.*, 2000; P. Dutton, NMFS, personal communication, January, 2001). The representation of loggerhead turtles in the longline fisheries is roughly proportional to patterns of loggerhead abundance in the Pacific basin. Therefore, it is reasonable to expect between 102 and 195 juvenile and subadult loggerhead turtles from the Japanese nesting stock would be killed each year in the Hawaii-based longline fishery.

We believe it is reasonable to expect that killing up to 195 juvenile and subadult loggerhead turtles each year would reduce the numbers of individuals in the species. Assuming that some of these turtles would be female, we would also conclude that these deaths would reduce the species' reproduction in addition to reducing their numbers. Assuming that turtles captured and killed in the fishery are proportional to their relative abundance in the action area, the Japanese nesting population of loggerhead turtles would experience the larger reduction in reproduction and numbers.

We also believe it is reasonable to expect that these mortalities will appreciably reduce the loggerhead sea turtles' likelihood of surviving and recovering in the wild, particularly given the status and trend of loggerhead turtle populations in the Pacific basin. Loggerhead turtles only nest in the western Pacific basin, primarily Japan and Australia. The only major nesting beaches for this species are in the southern part of Japan (Dodd, 1988). Balazs and Wetherall (1991) speculated that 2,000 to 3,000 female loggerheads may nest annually in all of Japan; however, more recent data suggest that this nesting colony current consists of about 1,000 female loggerhead turtles (Bolten *et al.* 1996). Quantitative data on the number of female loggerhead turtles returning to this colony since 1995 are unavailable, but qualitative reports suggest that this colony continues to decline (Tillman, 2000). Loggerhead turtles may also nest along the south China Sea, but it is a rare occurrence (Marquez, 1990, *in* Eckert, 1993).

In the south Pacific, Limpus (1982) reported an estimated 3,000 loggerheads nesting annually in Queensland, Australia during the late 1970s. However, long-term trend data from Queensland indicate a 50 percent decline in nesting by 1988-89, due to incidental mortality of turtles in the coastal prawn fishery. This decline is corroborated by studies of breeding females at adjacent feeding grounds (Limpus and Reimer, 1994). By 1997, the number of females nesting annually in Queensland was thought to be as low as 300 (1998 Draft Recovery Plan for Marine Turtles in Australia). Survey data are not available for other nesting assemblages in the south Pacific. Scattered nesting has also been reported on Papua New Guinea, New Zealand, Indonesia, and New Caledonia; however, population sizes on these islands remain unknown (NMFS and USFWS, 1998c).

In the *Environmental Baseline* section of this Opinion, we noted that loggerhead turtles are captured, injured, or killed in numerous Pacific fisheries including Japanese longline fisheries in the western Pacific Ocean and South China Seas; direct harvest and commercial fisheries off Baja California, Mexico, commercial and artisanal swordfish fisheries off Chile, Columbia, Ecuador, and Peru; purse seine fisheries for tuna in the eastern tropical Pacific Ocean, and California/Oregon drift gillnet fisheries.

Because of limits in the available data, we cannot accurately estimate the number of loggerhead turtles captured, injured, or killed through interactions with these fisheries. However, between 3 and 11 loggerhead turtles were estimated to have died annually between 1990 and 2000 in interactions with the California/Oregon drift gillnet fishery; approximately 1,950 loggerhead turtles are estimated to die annually in fisheries and direct harvest off of Baja, California; and before 1992, the North Pacific driftnet fisheries for squid, tuna, and billfish captured an estimated 2,986 loggerhead turtles each year, killing about 805 of them each year. Little data on the life stage or sex of captured animals is available; however, it is reasonable to expect that both incidental and intentional takes affect the larger pelagic juveniles and sub-adult life stages of this species.

In summary, the abundance of loggerhead turtles on nesting colonies throughout the Pacific basin have declined dramatically over the past 10 to 20 years. Loggerhead turtle colonies in the western Pacific Ocean have been reduced to a fraction of their former abundance by the combined effects of human activities that have reduced the number of nesting females and reduced the reproductive success of females that manage to nest (for example, egg poaching).

Changes in the survival of juvenile and sub-adult stages of loggerhead turtles can have the most significant, short-term effects on the status and trend of these turtle populations. Crouse *et al.* (1987), Crouse (1999), Heppell (1999), Ebert (1999), and Caswell (2001) constructed population models of loggerhead sea turtles and conducted what are called elasticity analyses (which, in this case, represent the relative contribution of different life stages to the long-term trend of the species). All of these analyses suggest that small juveniles and breeding adults made the most significant contribution to the growth of loggerhead turtle populations, followed by sub-adults and large juveniles. The additional juvenile mortalities associated with the U.S. pelagics fisheries would significantly increase the death rate of juvenile loggerhead turtles, which can be expected to appreciably reduce the population's ability to sustain its size.

As discussed previously, the Japanese population of loggerheads is declining, we infer that the rate at which sub-adult females are recruiting into the adult, breeding population is lower than the death rate of breeding, adult females (that is, adult females are dying without replacing themselves). The loss of an additional 102 to 195 juvenile or subadult loggerhead turtles from this population each year would reduce the number of animals that recruit into the adult population to replace adult that die which, in turn, reduces the future number of young the population can produce. The loss of these juvenile turtles would have a short-term effect on the number of breeding adults in this population (which is already declining) and short- and long-term effects on the birth rates of this population, which will have longer-term effects on the number of breeding adults. This would be expected to increase the population's rate of decline, which would increase the population's risk of extinction.

For example, in the minimum estimated time it would take the survivors of the 2001 cohort of eggs to recruit into the adult, breeding population (approximately 25 years), about 4,875 juvenile loggerhead turtles would have been killed in interactions with the longline component of the Pelagic FMP fisheries, if projected death rates remained constant. If the 195 loggerhead turtles captured and killed in this fishery each year *are* replaced in the same time interval by equal or greater numbers of maturing turtles,

then the mortalities caused by the longline fishery should not appreciably affect the loggerhead turtle's likelihood of surviving or recovering in the wild. On the other hand, if the 195 loggerhead turtles captured and killed in this fishery each year *are not* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery could threaten this population's likelihood of surviving and recovering in the wild. Unfortunately, we do not have enough information on the age structure of this population or age-specific survival rates to determine which of these two scenarios is more likely. However, the declining status and trend of this population suggests that dying adults and sub-adults in this population are not replaced by equal numbers of maturing juveniles and sub-adults.

Therefore, if the 195 loggerhead turtles captured and killed in this fishery each year *are not* replaced in the same time interval by equal or greater numbers of maturing turtles, as many as 4,875 adult loggerhead turtles will have been permanently removed from the Japanese nesting stock within the next 25 years. Removing these numbers of reproductive adults and pre-reproductive sub-adults from this declining population, would be expected to reduce the reproductive success of the Japanese nesting stock, which would, in turn, reduce or eliminate this population's ability to recover from its high rate of decline. This would appreciably diminish this population's likelihood of surviving in the wild, although we cannot quantify the exact magnitude of this effect. Given the current abundance of nesting females at Japanese beaches, if the Pelagics FMP fisheries were the only fisheries taking loggerhead turtles during this period, this impact alone could have serious consequences for the survival and recovery of the loggerhead Japanese nesting stock. Given the small size of this population, this is an appreciable reduction in the population size and reproductive capacity that would be expected to appreciably increase this population's risk of extinction.

In other biological opinions on fisheries in the Pacific Ocean, NMFS concluded that any additional reductions in the size of the Japanese nesting stock of loggerhead turtles are likely to maintain or exacerbate the decline of the loggerhead turtle (e.g., NMFS 2000d). This would further hinder population persistence or attempts at recovery as long as mortalities exceed any possible population growth, which appears to be the current case. Additional reductions in the likelihood of persistence of Japanese loggerhead stocks are likely to affect the overall persistence of the entire Pacific Ocean loggerhead population by reducing genetic diversity and viability, representation of critical life stages, total population abundance, and resilience as sub-populations are extirpated. These effects would be expected to appreciably reduce the likelihood of both the survival and recovery of the loggerhead turtle.

D. Olive Ridley Turtle

The proposed U.S. pelagic fisheries in the western Pacific Ocean will capture, injure, or kill adult and subadult olive ridley sea turtles. Virtually all of the olive ridley turtles that would be harmed incidental to the prosecution of fisheries under the Pelagics FMP are affected by the longline fisheries (the number of olive ridley turtles adversely affected by other fisheries included in this FMP are expected to be minimal – if any takes occur at all). Based on past patterns of olive ridley turtles captured in the Hawaii-based longline fishery, these turtles may be taken throughout the year, with most of the take occurring during the warmer months (May-August); and, past takes have been primarily concentrated in areas

surrounding the Hawaiian Island chain.

The proposed action is expected to result in the annual incidental capture of 48 and 98 adult or sub-adult olive ridley turtles by the Hawaii-based longline fishery. Most of these turtles will probably be hooked, rather than entangled, with slightly more of them being hooked internally; internal hooking is expected to kill more turtles than external hooking. Therefore, between 48 and 98 of the olive ridley turtles captured in this fishery would die each year as a result of the interaction. In the past, swordfish or mixed target-style gear has had a higher interaction rate of captures (0.0144 olive ridley turtles per set) and subsequent injuries and deaths of olive ridley turtles than tuna-style gear (0.0042 turtles per set); we expect this pattern to continue.

Recent genetic information analyzed from 20 olive ridleys taken in the Hawaii-based longline fishery indicate that 60% of the turtles originated from the eastern Pacific (Mexico and Costa Rica) and 40% of the turtles were from the Indian and western Pacific beaches (P. Dutton, NMFS, personal communication, January, 2001), indicating the animals from both sides of the Pacific converge in the north Pacific pelagic environment and may be equally affected by the proposed action.

If the longline fisheries affect olive ridley turtle populations proportional to their relative abundance in the action area (as documented through observer data), about 60 percent of the olive ridley turtles that are captured, injured, or killed by the longline fisheries would come from eastern Pacific populations. The remaining 40 percent would represent western Pacific populations. Using this assumption, it is reasonable to expect about 59 sub-adult or adult olive ridley turtles from the eastern Pacific population and another 39 sub-adult or adult olive ridley turtles from the western Pacific population would be killed each year in the Hawaii-based longline fishery. Further, it would be reasonable to expect that more of these olive ridley turtles would be taken by the swordfish/mixed target component of the fishery based on that component's higher interaction rates.

We believe it is reasonable to expect that killing up to 98 adult or sub-adult olive ridley turtles each year would reduce the numbers of individuals in the species, particularly since population estimates for this species are based on estimated numbers of adult turtles. Assuming that some of these turtles would be female, we would also conclude that these deaths would reduce the species' reproduction in addition to reducing their numbers. Assuming that turtles captured and killed in the fishery are proportional to their relative abundance in the action area, the western Pacific population of olive ridley turtles would experience the larger reduction in reproduction and numbers.

We do not believe it is reasonable to expect that these mortalities will appreciably reduce the olive ridley sea turtles' likelihood of surviving and recovering in the wild, because of the status and trend of olive ridley turtle populations in the Pacific basin. Historically, an estimated 10 million olive ridleys inhabited the waters in the eastern Pacific off Mexico (Cliffon, *et al.*, 1982 in NMFS and USFWS, 1998d). However, human-induced mortality led to declines in this population. Beginning in the 1960s, and lasting over the next 15 years, several million adult olive ridleys were harvested by Mexico for commercial trade with Europe and Japan. (NMFS and USFWS, 1998d). Although olive ridley meat is palatable, it was not widely sought after; its eggs, however, are considered a delicacy. Fisheries for

olive ridley turtles were also established in Ecuador during the 1960s and 1970s to supply Europe with leather (Green and Ortiz-Crespo, 1982).

In the eastern Pacific, nesting occurs all along the Mexico and Central American coast, with large nesting aggregations occurring at a few select beaches located in Mexico and Costa Rica. The largest known *arribadas* in the eastern Pacific are off the coast of Costa Rica (about 475,000 to 650,000 females estimated nesting annually) and in southern Mexico (about 800,000 or more nests per year at La Escobilla, in Oaxaca; Millán, 2000). The greatest single cause of olive ridley egg loss comes from the nesting activity of conspecifics on *arribada* beaches, where nesting turtles destroy eggs by inadvertently digging up previously laid nests or causing them to become contaminated by bacteria and other pathogens from rotting nests nearby.

The nationwide ban on commercial harvest of sea turtles in Mexico, enacted in 1990, appears to have improved the situation for the olive ridley. Surveys of important olive ridley nesting beaches in Mexico indicate increasing numbers of nesting females in recent years (Marquez, *et al.*, 1995; Arenas, *et al.*, 2000). Annual nesting at the principal beach, Escobilla Beach, Oaxaca, Mexico, averaged 138,000 nests prior to the ban, and since the ban on harvest in 1990, annual nesting has increased to an average of 525,000 nests (Salazar, *et al.*, in press).

Olive ridleys are not as well documented in the western Pacific as in the eastern Pacific, nor do they appear to be recovering as well (with the exception of Orissa, India in recent years). There are a few sightings of olive ridleys from Japan, but no report of egg-laying. Nesting information from Thailand indicates a marked decline in olive ridley numbers primarily due to egg poaching, harvest and subsequent consumption or trade of adults or their parts (i.e. carapace), indirect capture in fishing gear, and loss of nesting beaches through development (Aureggi, *et al.*, 1999). Extensive hunting and egg collection, in addition to rapid rural and urban development, have reduced nesting activities in Indonesia as well.

Olive ridley nesting is known to occur on the eastern and western coasts of Malaysia; however, nesting has declined rapidly in the past decade. The highest density of nesting was reported to be in Terengganu, Malaysia, and at one time yielded 240,000 eggs (2,400 nests, with approximately 100 eggs per nest) (Siow and Moll, 1982, *in* Eckert, 1993), while only 187 nests were reported from the area in 1990 (Eckert, 1993).

In contrast, olive ridleys are the most common species found along the east coast of India, migrating every winter to nest en-masse at three major rookeries in the state of Orissa, Gahirmatha, Robert Island, and Rushikulya (*in* Pandav and Choudhury, 1999). The Gahirmatha rookery, located along the northern coast of Orissa, hosts the largest known nesting concentration of olive ridleys. Unfortunately, uncontrolled mechanized fishing in areas of high sea turtle concentration, primarily illegally operated trawl fisheries, has resulted in large scale mortality of adults during the last two decades. Fishing in coastal waters off Gahirmatha was restricted in 1993 and completely banned in 1997 with the formation of a marine sanctuary around the rookery. Threats to these sea turtles also include artificial illumination and unsuitable beach conditions, including reduction in beach width due to erosion (Pandav

and Choudhury, 1999). According to Pandav and Choudhury (1999), the number of nesting females at Gahirmatha has declined in recent years, although after three years of low nestings, the 1998-99 season showed an increasing trend, and the 1999-2000 season had the largest recorded number of olive ridleys nesting in 15 years when over 700,000 olive ridleys nested at Nasi islands and Babubali island, on the Gahirmatha coast.

Given initial population sizes and increases in the Mexican and Costa Rican populations in recent year, the mortalities associated with the U.S. pelagics fisheries are not likely to halt or reverse the increasing trend of those populations. Removing adult or sub-adult turtles from the eastern Pacific population could slow the recovery of the population that is occurring, although it is not clear if that reduction would be measurable given the size of the nesting population.

The cumulative effect of the fisheries do not seem likely to affect the status and trend of the olive ridley population. In the time it would take the survivors of the 2001 cohort of eggs to recruit into the adult breeding population (approximately 9 years), about 531 adult or sub-adult eastern Pacific olive ridley turtles would have been killed in interactions with the longline component of the pelagic fisheries, if projected death rates remained constant. If the 59 eastern Pacific adult or sub-adult olive ridley turtles captured and killed in this fishery each year *are* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery should not appreciably affect the olive ridley turtle's likelihood of surviving or recovering in the wild. On the other hand, if the 59 eastern Pacific adult or sub-adult olive ridley turtles captured and killed in this fishery each year *are not* replaced in the same time interval by equal or greater numbers of maturing turtles, then the mortalities caused by the longline fishery could threaten this population's likelihood of surviving and recovering in the wild. The increasing status and trend of this population, suggests that adults and sub-adults that die in this population *are* being replaced by equal (or greater) numbers of maturing juveniles and sub-adults.

Population trends in the western Pacific are more difficult to discern, although it is clear that there are still large populations of olive ridleys nesting in India. Killing adult and sub-adult turtles in the western Pacific population could have more serious consequences, since this population continues to be affected by ongoing factors such as incidental take in fisheries, the harvest of eggs on nesting beaches, and inundation and erosion of beaches. By removing reproductive adults and pre-reproductive sub-adults from this declining population, the proposed action could adversely affect the future persistence of the population, although it is unknown how much, or to what degree, this might impact the population's survival in light of the other factors currently affecting this population.

Nevertheless, the major populations of olive ridley turtles in the Pacific Ocean appear to be increasing, despite some residual, adverse effects of fishery-related mortalities and harvest of adults and eggs. Because of the population size, number of reproductive females, and the rates at which sub-adults are recruiting into the adult population, we believe this population can withstand the mortalities and reduced reproductive rates associated with the U.S. pelagics fisheries without appreciable reductions in the olive ridley turtle's likelihood of the surviving and recovering in the wild.